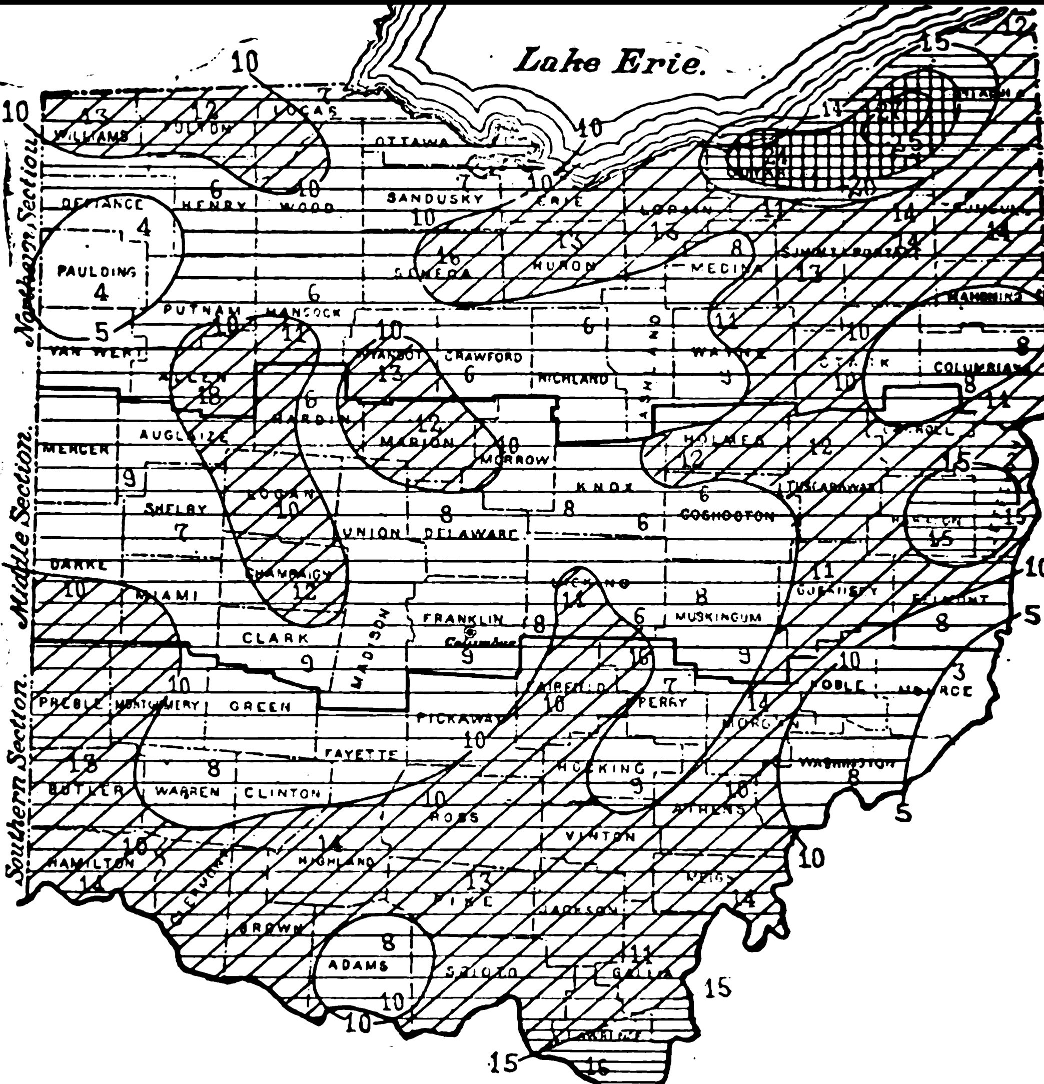

Bulletin

Ohio Agricultural Experiment Station

MINERAL AND ORGANIC ANALYSES OF FOODS

OHIO

Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JANUARY, 1913.

BULLETIN 255

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MINERAL AND ORGANIC ANALYSES OF FOODS

NEW METHODS FOR THE DETERMINATION OF SODIUM AND CRUDE FIBER

By E. B. FORBES, F. M. BEEGLE AND J. E. MENSCHING

In the course of the investigations of this laboratory there have been accumulated a considerable number of food analyses, which, it is thought, may be of sufficient interest to students of nutrition to warrant their publication. These analyses cover an extensive range of substances including representatives of all the groups of food products, and comprise determinations of both organic and inorganic constituents. The tables include also computations of the balance of acid to basic elements in foods, as made by Sherman and Sinclair*, which call attention in a useful way to an important detail in their character.

Few of our American agriculturists have given attention to the mineral elements in foods, and most of those who have made ash analyses have been students of soil fertility rather than animal nutrition, and so have prepared their samples for analysis in such a way as to indicate the draft upon the soil rather than the value of the products as animal foods. In our analyses, only such parts of the natural products are represented as are edible by the kind of animal usually consuming them.

These analyses do not include determinations of iron. While this is a matter of some importance, as related to human nutrition, the contamination of the samples with iron in the usual methods of preparation probably exceeds the amount properly present, and the special preparation necessary for accurate iron estimations was not practicable under the conditions attending this work.

*Sherman and Sinclair: Jour. Biol. Chem., Vol. 4, No. 2, 1908.

Most of the inorganic analyses of foods in our text and reference books are both ancient and foreign. Considerable progress has been made in recent years in analytical methods, and the ash content of foods is much influenced by soil and climate. It is thought, therefore, that recent analyses, by approved methods, of American-grown products have a value to American students which is not possessed by the older work of European agriculturists.

It is not our purpose to present anything like a complete series of food analyses, nor a general discussion of nutrition, but in view of the amount of labor involved in such determinations, simply to record those which we have so that they may be of use, and also to point out some of the more important truths which they exemplify.

The usual organic food analyses are not discussed in this article, although these determinations are included in the tables on pages 225 to 231, and are here recorded for reference in connection with the mineral analyses.

CHEMICAL METHODS

The chemical methods followed in this work are as indicated below:

Ash: On vegetable substances, the hydrochloric acid leaching method, (see Ohio Bul. 222, p. 44); on animal products by the official water-leaching method.

Moisture: Vacuum method, over sulphuric acid.

Nitrogen: Gunning method.

Fat: Ether extract.

Crude Fiber: Original method; see below.

Sodium: Original method; see below.

Potassium: Lindo-Gladding method.

Calcium and magnesium: McCrudden method.

Sulphur: Provisional peroxide method of the A. O. A. C.

Chlorine: Provisional method of the A. O. A. C. for plant substances.

Phosphorus: Official gravimetric method. With vegetable substances this determination was made on a hydrochloric acid solution of the ash; with animal products, except egg, it was made in the same way; with egg the oxidation was accomplished by the nitric-sulphuric acid digestion method.

Inorganic phosphorus: Methods of this laboratory published in Ohio Bul. 215.

CRUDE FIBER METHOD

The crude fiber method used in this work is an improvement on the Morgan P. Sweeney modification of the official method, the improvements consisting in filtration through asbestos and sand

in a Gooch crucible, treatment with hydrochloric acid, washing without transfer, and ignition in the Gooch crucible. The details are as follows:

To a 1 or 2 gram sample add 200 c. c. of boiling 1.25 percent sulphuric acid, and boil for 30 minutes.

Neutralize with 10 percent sodium hydrate using phenolphthalein as an indicator; add 200 c. c. of 2.656 percent boiling sodium hydrate; make volume up to 425 c. c. and boil for 30 minutes.

Filter through a porcelain Gooch crucible containing an asbestos pad and 10-12 grams (½ inch) of very fine acid-washed sand,* compacted by water and suction. Treat with 1.25 percent hydrochloric acid, wash with hot water until free from chlorides, and then with alcohol and ether; dry, weigh, ignite and weigh. The difference in weights represents crude fiber.

The improved method sometimes gives higher figures than the official method. In general the results check, one with another, very satisfactorily, and the method is much easier to use.

The unsatisfactory character of the official method is too well known to require comment. This new procedure eliminates all transfer of the sample, and also the unstandardized cloth strainer, for which it substitutes a filter which is thoroughly efficient, and which at the same time allows of very rapid filtration of solutions, such as those from linseed and cottonseed meals, which are very difficult of filtration by any other method. The use of hydrochloric acid facilitates the final washing A microscopical examination of the crude fiber and the filtrates from the official, and from our modified methods showed that the higher results obtained by the latter were due to undissolved, woody and chitinous particles which passed through the linen but which were retained by the sand and asbestos. In the products examined there was no evidence of contamination of the crude fiber as determined by the improved method by gummy or protein substances.

Objection to the Sweeney method has been raised on account of difficulty with the colored extracts of some feeds in determining the neutral point. This objection is not insuperable in any case, and in using this method with the wide range and considerable number of products included in this discussion we found that it was in rare instances only that the color of the extract interfered with the use of the indicator.

The slow filtration by the Sweeney method is entirely overcome in our modification.

*Sand satisfactory for this purpose has been purchased from the Berkshire Glass Sand Co. of Cheshire, Mass. Coarse sand was found not to be useful, the reason being that it allows the fiber to pass through and then to clog the asbestos pad. Do not use more sand than experience shows to be necessary, on account of the difficulty of washing it free from chlorides.

Objection has also been raised to the Sweeney method on account of possible interference of the fat with the solution of the acid- and alkali-soluble constituents. This possibility, however, has not been proven appreciably to affect results.

Whatever the method under consideration, we are unable to judge of its accuracy by comparison with the official method, because of the lack of definiteness as to the character of the cloth strainer, and because of the incomplete retention of the crude fiber of some products by such a filter.

Below are a few determinations made by our improved method, in comparison with results from the official procedure. The sample in each case weighed one gram. The figures are weights in grams of crude fiber.

	Official method	Modified method
Cowpeas	.0544 .0560 .0570	.0568 .0564 .0554
Linseed oil meal	.0922 .0908 .0910	.1110 .1118 .1112
Corn meal	.0228 .0212 .0238	.0272 .0280 .0272
Soybeans	.0470 .0472	.0482 .0484
Distiller's grains (corn)	.1232 .1228	.1239 .1240
Oats, grain	.1215 .1212	.1217 .1215
Wheat bran	.0837 .0830	.0856 .0868
Wheat, grain	.0324 .0331	.0332 .0332
Patent flour	.0010 .0012	.0025 .0025
Gluten feed	.0892 .0891	.0886 .0881
Cottonseed meal	.0705 .0703	.0710 .0720

SODIUM METHOD

The reason for attempting an improvement on the official method for the estimation of sodium is that by this method it is very difficult entirely to free the combined sodium and potassium sulphates from phosphates. To get duplicate results which check is not so difficult; but a test for phosphorus is very apt to demonstrate the impurity of the salts. We do not affirm that it is impossible to free the sulphates from phosphates by the official method, but the amount of manipulation often necessary for the attainment of this

result is apt to leave one without faith in the determination. The new method gives better checks, requires less manipulation, and the sulphates are not contaminated by phosphates. The procedure is as follows:

METHODS OF PREPARING SOLUTION

(a) Digest sample with nitric and sulphuric acids in a Kjeldahl flask as for a phosphorus estimation;* make the solution up to volume; take for the determination such aliquots as will represent 2-4 grams each of the fresh substance, and neutralize with ammonia; or (optional):

(b) Moisten the sample with dilute sulphuric acid, and burn at a temperature below red heat. Digest the ash in dilute hydrochloric acid and filter; bring the filter paper and residue to dryness in a platinum dish; ignite; digest in hot water; filter, and add the filtrate to the one resulting from the first ignition; make the solution up to volume, and take for the determination such aliquots as will represent 2-4 grams each of the fresh substance.

DETERMINATION

Precipitate out the phosphorus with magnesia mixture and 10 cc. of ammonia. Allow to stand over night, and filter into a beaker.

Evaporate the filtrate to a low volume, transfer to a platinum dish, bring to dryness, and continue heating on a sand bath until ammonia fumes are evolved; then burn off all ammonium salts over a flame.

Take up the residue in the platinum dish with hot water; transfer to a beaker, and heat; then add enough freshly prepared barium hydrate solution completely to precipitate the magnesium. Let the precipitate settle for a few minutes, and test for complete precipitation. When no further precipitation is produced, filter, and wash thoroughly with hot water.

Heat the filtrate to boiling; make alkaline with ammonia, and add ammonium carbonate to precipitate the barium, calcium, etc.

Filter into a beaker; add a drop or two of hydrochloric acid and 1 c. c. of ammonium sulphate solution, (75 gr. per liter), and digest for several hours on a steam bath.

Transfer into a platinum dish, evaporate to dryness and ignite; dissolve in hot water and filter into a weighed platinum dish, in which evaporate, ignite, heat to constant weight, and weigh as sodium and potassium sulphates.

Note—All ammonium salts must be driven off after precipitation of the phosphorus with magnesia mixture. The barium hydrate solution must be freshly prepared.

*The sulphuric and nitric acid digestion seems not to introduce a perceptible error through the solution of the Jena glass flask in which this process is conducted.

Below are a few estimations made by the official and by the new methods. The figures represent grams of sodium and potassium sulphates from 1 gram of substance.

	Official method*	New method
Distiller's grains	.0039 .0049	.0034 .0035
Snake weed	.0227 .0333	.0180 .0180
Cottonseed meal	.0529 .0563	.0479 .0484
Brewer's grains	.0151 .0239	.0132 .0124

Some determinations by the new method alone are as follows:

Apple	.0194 .0203	Milk	.0448 .0411	Peanuts	.0185 .0189
Banana	.0194 .0184	Eggs	.0165 .0165	Rice	.0018 .0018
Sweet potato	.0384 .0390	Alfalfa hay	.0334 .0339	Tankage	.0705 .0692
Navy beans	.0334 .0333				

DISCUSSION OF MINERAL ANALYSES

Perhaps a useful suggestion to the student of these tables is that the inorganic products vary remarkably in accord with the conditions of growth, especially as relating to soil, rainfall and sunshine, and also rapidity of growth and stage of maturity attained. The variation in organic constituents, however, is very much less than in mineral elements. This variability is much more prominent in roughage and roots than in cereals and fruits. The general character only of the ash analysis of a vegetable product remains characteristic.

In the interpretation of these analyses we may keep in mind certain observations as follows:

(1) In general, a high ash content of the food is desirable, since the animal is better able to cope with an excess of ash constituents than with a deficiency.

(2) The greatest deficiency in the mineral nutrients of common foods is in calcium (lime).

(3) Phosphorus is also often deficient.

(4) The other mineral elements are not likely to be deficient in common foods, except for sodium and chlorine, which are usually added in superabundant measure as common salt.

(5) Magnesium contributes more than other mineral elements to the laxative character of foods.

*The weights of sulphates by the official method fail to check by reason of contamination with phosphates. Test showed no phosphates present in sulphates obtained by the new method.

(6) Foods which are high in ash constituents generally are apt to be laxative, while those which are low in ash are often constipating.

(7) An excess of basic mineral elements over acid mineral elements in the food is desirable. The body is able to compensate for a certain excess of acid, but this capacity is limited. Too close an approach to this limit is a disadvantage to the animal, and restricts the growth of bone; if it is exceeded death ensues.

(8) Sodium and chlorine are always available in the form of salt. Potassium and magnesium are probably always present in sufficient quantity in practical rations. Sulphur is present in foods almost entirely in their protein compounds, and hence varies with the protein, and is not lacking if the ration is properly balanced in regard to nitrogenous and non-nitrogenous nutrients. Calcium and phosphorus alone are frequently lacking in otherwise well balanced rations, though iron is also occasionally deficient.

(9) Those animals with which the mineral nutrients are most important are young, growing animals, and pregnant, milk-giving or egg-laying females. The mature work animal needs comparatively little mineral matter.

WHEAT PRODUCTS

Considering the cereals as essential components of practical rations of both man and his animals, let us examine the ash analyses of cereal products, and also those of other foods which may be used with the cereals. (Table I., p. 225.)

Among the various products of the wheat grain our greatest interest is in the white flour. It contains less mineral matter than any other wheat product, and therefore requires that the mineral necessities for growth be very largely provided by other articles in the dietary. Not only is the total ash low but the individual elements are each one present in very small quantities, and hence we must regard white flour as a poor food for all purposes served by mineral matter. In every-day life the one deficiency of white flour which is most likely to make itself apparent is its lack of magnesium, this deficiency causing its constipating character, a matter of no concern to most healthy adults, but one of much importance in the feeding of the very young and others who for any reason must subsist on a diet of limited variety. Actual disease is probably not often caused by the lack of mineral matter in white flour, though there is reason to believe that beriberi, as found in certain communities of poor fishing-folk in Labrador, may be caused by the mineral deficiencies of the diet, which consists during the winter months largely of white bread and tea.* Whatever the exact cause of this malady it

*Little, J. M., Journ. Am. Med. Assn., vol. 58, p. 229.

is readily curable by the use of the coarser parts of the wheat, as was first proven on a large scale when a ship-load of whole-wheat flour was wrecked on the Labrador coast at a point where beriberi was prevalent. Much disadvantage of a less acute degree may fairly be attributed to the mineral deficiencies of white flour. Among the many methods available for getting the minerals of the wheat into the dietary, as wholesome as any, and the cheapest, is the use of graham bread.

Next after wheat flour wheat bran is the best known wheat product. It contains about 3.5 times as much ash as does wheat, and on this account is popularly supposed to be a good bone food. This, however, is an erroneous impression. Bran by itself is a very poor bone food, so poor that an excessive use of bran causes a well known bone disease, "miller's horse rickets," "bran disease" or "shorts disease." The characteristic of bran which makes it a poor bone food is its low calcium content. Bran is very rich in magnesium, to which fact is due in part its well known laxative tendency.

The high phosphorus content of bran is its greatest mineral asset, though it is not possible for the animal to make use of this phosphorus unless other foods in the ration supply the calcium with which most of the phosphorus must be united in its use by the animal.

The mineral bases which are present in bran in such large amounts contribute but little to its value as a foodstuff, since the predominating ones, magnesium and potassium, are not used by the animal in large quantities, and are those which are almost invariably present in excess in ordinary rations.

Wheat middlings possess the same general character as wheat bran, as regards mineral content, though the amount present of each constituent is somewhat less; but the same lack of balance between the elements prevails, as is attested by the fact that a pig will not thrive long on middlings alone, nor for many months on corn and wheat middlings, if no other food be allowed. To get the best use of middlings or bran, or indeed, of any other cereal food, it must be used with other foodstuffs containing much more calcium.

The lowest grade of wheat flour, known as "red dog," and which is used for feeding purposes, has a mineral composition much like that of wheat middlings, but contains very much less potassium Potassium and crude fiber vary in a general way together, in these wheat products, and indeed in many other foods.

Wheat germs are used by large manufacturers in the preparation of human foods. The small miller, however, puts them into the middlings. Though obtainable they are not on the general market

unmixed with other parts of the wheat. Chemically they are of interest because of their high content of nuclein phosphorus, but no especial advantage has been found to depend upon the fact that the phosphorus is present in this particular condition.

Wheat gluten is prepared as a flour for diabetics. The most marked peculiarity of its ash analysis is its high sulphur content, this being due to its being almost a pure protein, the sulphur being present almost wholly as a constituent of the nitrogenous compounds.

In common with other cereals the wheat preparations have almost equivalent amounts of acid and basic mineral elements, but usually with a slight preponderance in favor of the acids. A considerable excess of base in the remainder of the ration would therefore be desirable. In common with other cereals the wheat products also have their phosphorus present almost entirely in organic forms.

The wheats represented by the mineral analyses in Table IV, p. 228, are from the 1911 crop of the 5-year rotation series of the Soils Department of this Station. As was demonstrated by the extensive work of J. W. Ames, published in Bulletin 221 of this Station, there are marked variations of the composition of the wheat grain in accord with the fertilizers applied, but when we consider these variations as indications of food value we find that their magnitude is not such as to render them practically important. In actual practice variations in the calcium and phosphorus of rations are alone likely to be of importance. The range of variation of calcium in these wheats is .013 of one percent, and the variations in phosphorus cover a range of .069 of one percent. Now, when we consider the small proportions of these amounts of calcium and phosphorus in wheat which are present in wheat flour, we appreciate the fact that these variations are not important in connection with human nutrition, though the differences in mineral nutriment in the *different* human foods are matters of importance, and should enter into the determination of our choice from among those available; and it is also true, as we have shown in Ohio Bulletin 222, that the roughages fed to animals vary in accord with the fertility of the soil to such extent as is practically important.

CORN PRODUCTS

Corn (maize) contains less ash than wheat (Table I, p. 225); less ash than any of our cereals except Kaffir corn and related species, and is in general the poorest bone food available to the stock feeder. Its

economical utilization by growing or breeding animals, or animals producing milk or eggs, requires that foods used with corn should contain decidedly more calcium than corn contains. The deficiency of corn in calcium is much greater than in protein.

Bolted corn meal, as prepared for human consumption, lacks the skin and a portion of the germ of the kernel. The exclusion of these portions of the grain still further lowers the value of the product to a growing animal. The germ is removed from corn in the manufacture of meal for human consumption in order to increase its keeping quality. Corn meal containing the germs becomes musty much more quickly than meal from which they have been excluded.

Corn bran is not generally on the market. Those business interests which control the manufacture of corn products in this country find that the most profitable way to dispose of the corn bran is to grind it fine, and then to mix it with products of greater food and market value; corn germ meal and gluten meal in the pure state have, therefore, been generally withdrawn from the market, and are usually obtainable only mixed with corn bran, and are then known as hominy feed and gluten feed. Corn bran, because of its indigestible character, has a low feeding value.

Pearl hominy contains less mineral nutriment than any other of the corn products, since in its manufacture the skin and germ are removed more completely than in the manufacture of bolted corn meal.

Distiller's grains from corn also contain but little mineral nutriment.

Gluten feed contains more mineral nutriment than other corn products, though not so much as the other nitrogenous concentrates, linseed and cottonseed meals. The difference in the mineral nutrients of these concentrates should enter more largely into the determination of the market price than it does, considering them both as animal foods and as sources of soil fertility.

OTHER CEREAL PRODUCTS

Distiller's grains from rye and brewer's grains and malt sprouts from barley, contain somewhat more mineral nutriment than does corn, but are not notable in this regard. The same may be said of oats. The high ash content of oats is due largely to the silica in the hull.

Polished rice contains less mineral nutriment even than any corn product, and too large a use of polished rice is the usual cause of beriberi. The use of unpolished rice prevents and cures this disease.

Rice polish is exceedingly rich in potassium, magnesium and phosphorus. The general character of the ash analysis is much as in wheat bran. In common with all the cereal foods it is very low in calcium.

Considering these cereals and cereal products as a group, we observe that from the point of view of this discussion the dominant characteristic which they have in common is the lack of lime. The acid mineral elements slightly and rather uniformly exceed the basic elements, and the phosphorus is almost wholly organic. Wheat bran, wheat middlings, red dog flour, and rice polish are remarkable because of high phosphorus contents, which would be an advantage in rations containing the calcium necessary to the utilization of the phosphorus.

Considering the cereal products as human foods, the greater acceptability of the highly milled products is attained at a considerable loss of mineral nutriment, and the use of these modern products requires more careful consideration of the remainder of the diet than was necessary in the days of primitive milling processes.

Growing animals subsisting on cereals alone soon come to suffer from malnutrition of the bones.

Since the economical utilization of the cereals as foodstuffs is one of the most important of our problems, we now logically turn to those foods which are, by nature, adapted to supplement them.

LEGUMINOUS AND OTHER ROUGHAGE

The leguminous roughages, clover, soy bean, cowpea and alfalfa hays, taken as a group (Table II p. 226), in addition to a general similarityof mineral contents, are alike in the possession of a very high calcium content and a marked preponderance of basic over acid mineral constituents. Where the cereals are weakest, the leguminous roughages are strongest. Among the many reasons why we should raise legumes one of the most important is this natural fitness which they possess to make good the greatest mineral deficiency of our most highly valued field products, the cereals. In a general way this combination of cereal products and leguminous roughage makes a perfect ration. Other improvements are of a minor order.

Roughages are so variable in composition that it is not wise to attempt to compare one of these legumes with another on the basis of single analyses.

The cereal roughages, timothy and millet hay, blue grass, corn stover and wheat straw, are likewise characterized by an excess of basic over acid minerals, and are also richer in calcium than are the

seeds of the same plants. Both these desirable characteristics are possessed by these foodstuffs in much smaller measure than by the leguminous roughages, and they have, consequently, a lower value as supplements to the cereal grains for feeding purposes.

The phosphorus of roughages, both leguminous and cereal, is much more nearly equally divided between organic and inorganic compounds than in the grains, doubtless due to the greater transpiration of water by the leaves of plants than by the seeds, and thus to the consequent incidental residue of phosphates within their tissues.

LEGUMINOUS SEEDS AND CONCENTRATES

Leguminous seeds such as soybeans, navy beans, cowpeas, peanuts, etc., (Table III, p. 227) have very high feeding values; the range of their usefulness is wide, and is being rapidly extended. On the mineral side they are qualified to some extent to supplement the cereals, because of an excess of basic over acid mineral elements, and greater contents of calcium, but they possess both of these qualities in smaller measure than the roughages of the same species. Because of their high protein contents, and their limited capacities to make good the deficiencies of the cereals, their place in the dietary is often likened to that of meat.

Linseed and cottonseed meals are richer in calcium, magnesium and phosphorus than the leguminous concentrates. They do not differ from them widely in balance of acid to basic mineral elements. Their great usefulness in the rations of farm animals is due partially to their high mineral contents, and the elements of fertility contained in their residues have a value equal to a considerable part of the cost of the food. They are superior to gluten feed in all the ways in which the minerals affect the value of these products.

ANIMAL PRODUCTS

Among the animal products (Table III, p. 227) milk merits especial attention since it may fairly be considered a perfect animal food. It is characterized by an excess of basic over acid mineral elements, and contains considerably more calcium than phosphorus, and generous amounts of both of these, on the dry matter basis. Its phosphorus is a little more largely in inorganic than in organic compounds.

Whey contains a greater proportion of basic to acid mineral elements than does milk, since the curd removes more acid than basic mineral elements from milk. The ready assimilability of its organic constituents, and the corrective tendency of its minerals in the various digestive disturbances of infancy, especially those in which acidosis is a feature, make whey the rational basis for the modification of milk for infants. Perhaps no single bearing of this

matter of the mineral elements in nutrition is likely to cut more of a figure in the happiness of the average man than the use of whey rather than water in the modification of milk. Whey is also especially useful in severe illness of older children. Many a child has been taken through protracted sieges of fever on whey alone. Its mineral salts correct the tendency to acidosis in such diseases, and the milk-sugar and albumen contained are sufficient in amount to be of great value. It may be prepared fresh from skim milk by the use of the commercial rennet extracts obtainable at any drug store, or from the evaporated commercial product from which this analysis was made.

Meat, like the cereals, is extremely low in calcium, and like them, will cause malnutrition of the bones if used to the exclusion of other foods. Carnivorous animals naturally make good this deficiency by eating bones.

Tankage is a packing-house product consisting of a mixtue of meat and bone scrap, dried and ground. It is also apt to contain paunch contents, salt, sand, and other foreign matter. It is rich in all of the mineral nutrients, and makes a complete, and at least practically perfect supplement to the cereals for swine. Similar preparations serve the same purpose for poultry except that in addition poultry require a supply of calcium carbonate, which is most advantageously supplied as oyster shell.

"Banner bone flour" is a precipitated calcium phosphate prepared from bone, and consists of a mixture of the dicalcic and tricalcic phosphates, with the former predominating. It is a useful addition to a ration which lacks bone-forming constituents.

Finely ground bone has a certain advantage over the above-mentioned precipitated bone earths in its greater proportion of calcium to phosphorus, but is difficult to obtain in a sufficiently finely ground condition to be generally acceptable to live stock.

Blood preparations are useful as high-protein foodstuffs, but, like meat, are deficient in calcium.

Eggs also are low in calcium, a deficiency which the incubating chick makes good by withdrawing calcium carbonate from the shell. Eggs are rich in phosphorus, however, in organic compounds, mostly lecithin, which has a high nutritive value, and which is a universal cell constituent.

Considering the animal products as a group, they usually contain an abundance of phosphorus, but only milk and bone preparations contain enough calcium to make them of value on this account in supplementing the cereals.

FRUITS AND VEGETABLES

Fruits and vegetables (Table II, p. 226) have in common a very decided preponderance of basic over acid mineral nutrients, due largely to high potassium and low phosphorus contents, the bases being present as salts of organic acids which are oxidized in the body, the acid radicle being excreted as carbon dioxide and water, and the inorganic bases becoming free for the neutralization of mineral acids which cannot thus be oxidized to harmless products. This fits them admirably to serve as supplements to the cereals and leguminous seeds. They are, on the dry basis, moderately rich in calcium.

CONCLUSION

All things considered, then, the ration which is most likely to contain in abundance all of the mineral nutrients required by animals, is one characterized by diversity of origin, no one class of foods greatly exceeding others. A diet of cereals, or of meat, or eggs, or of any combination of these three, would not be well proportioned. Cereals and milk, or cereals and fruits, or cereals and vegetables, would make better proportioned dietaries.

Grouping together the foods with acid ash—cereals, meats and eggs, and opposing to them those of alkaline ash—fruits, vegetables, milk and legumes, the latter group should be liberally represented in the dietary.

Among single foods, milk and the legumes are perhaps more nearly complete foods on the mineral side than others, though there are many reasons why extreme simplicity of diet is not advantageous.

Those circumstances most likely to lead to error in this matter of the mineral elements in nutrition are poverty, parsimony, fads and indifference, in which connection we would repeat the expression of the old lady who prayed, "Oh Lord, make the indifferent different."

NOTE—Of the following tables, Nos. I, II and III are mineral analyses of foods stated on the dry basis. Tables V, VI and VII contain ordinary food analyses as well as mineral analyses and are stated on the fresh basis. These tables represent the same products as tables I, II and III, and the arrangement is the same. Table IV shows the effects of fertilizers on the wheat grain.

TABLE I—MINERAL ELEMENTS OF CEREAL PRODUCTS—PARTS PER 100 OF DRY SUBSTANCE.

	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Inorganic phosphorus	Organic phosphorus	C. C. Normal Solution per 100 Grams			
											Total base	Total acid	Excess base	Excess acid
Wheat	1.866	.590	.036	.066	.142	.224	.095	.425	.038	.387	31.10	44.11	....	13.01
Wheat flour	.192	.068	.127	.022	.019	.168	.081	.102	.017	.085	9.61	19.39	....	9.78
White bread	1.695	.156	.583	.038	.004	.198	.958	.135	.043	.092	31.46	48.10	....	16.64
Wheat bran	6.729	1.464	.223	.139	.590	.297	1.000	1.233	.034	1.199	102.42	100.88	1.54	.....
Wheat middlings	4.630	1.147	.186	.108	.430	.263	.029	.984	.069	.915	78.08	80.71	....	2.63
Wheat germ	5.147	.323	.788	.078	.372	.355	.077	1.147	....	....	76.81	98.31	....	21.50
Wheat gluten	.780	.007	.031	.085	.049	1.000	.055	.220	.037	.183	9.78	78.12	....	68.34
Red dog flour	4.151	.425	.733	.134	.324	.285	.156	.928	.098	.830	75.94	82.01	...	6.07
Corn	1.410	.396	.030	.014	.126	.171	.073	.303	.028	.275	22.43	32.31	...	9.88
Corn meal, bolted	.790	.192	.113	.015	.122	.122	.070	.264	.019	.245	20.56	26.62	....	6.06
Corn bran	1.330	.410	.000	.030	.088	.124	.052	.156	.031	.125	19.19	19.27	....	0.08
Pearl hominy	.600	.153	.000	.005	.036	.182	.062	.111	.019	.092	7.11	19.98	....	2.87
Gluten feed	3.460	.272	.461	.268	.239	.636	.098	.589	.106	.483	59.94	80 42	....	20.48
Distiller's grains, corn	1.500	.014	.154	.047	.054	.509	.085	.314	.056	.258	13.75	53.87	....	40.12
Distiller's grains, rye	3.692	.045	.077	.142	.195	.408	.028	.458	.018	.440	27.58	55.80	....	28.22
Brewer's grains	2.953	.185	.278	.169	.172	.419	.062	.503	.162	.341	39.29	60.31	....	21.02
Malt sprouts	6.153	.219	1.458	.159	.194	.864	.389	.746	.471	.275	92.72	112.99	....	20.27
Oats	3.709	.460	.184	.112	.130	.214	.077	.434	.059	.375	35.95	43.49	....	7.54
Kaffir corn	1.339	.288	.066	.013	.142	.186	.117	.271	.012	.259	22.51	32.42	....	9.91
Rice	.315	.040	.032	.009	.028	.114	.040	.104	.003	.101	5.12	14.89	....	9.77
Rice polish	8.024	1.279	.124	.030	.741	.189	.151	1.684	.028	1.656	100.38	124.72	....	24.34

TABLE II—MINERAL ELEMENTS OF FRUITS, VEGETABLES AND ROUGHAGE—PARTS PER 100 OF DRY SUBSTANCE.

	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Inorganic phosphorus	Organic phosphorus	C. C. Normal Solution per 100 Grams			
											Total base	Total acid	Excess base	Excess acid
Apple	1.807	.802	.066	.027	.033	.044	.037	.064	.033	.031	27.39	7.93	19.46	....
Prune	2.845	1.347	.045	.076	.056	.066	.050	.110	.098	.012	44.76	12.59	32.17	....
Banana	2.925	1.291	.240	.037	.129	.021	.421	.119	.089	.030	55.86	20.87	34.99	....
Date	1.920	.667	.115	.084	.086	.087	.285	.077	.037	.040	33.09	18.42	14.67	....
Onion	4.304	1.442	.097	.261	.136	.601	.183	.323	.210	.113	65.14	63.44	1.70	....
Cabbage	7.189	2.484	.028	.590	.209	.901	.243	.262	.136	.126	111.18	80.00	31.18	....
Potato, sweet	3.133	1.208	.061	.084	.215	.117	.069	.186	.138	.048	55.37	21.26	34.11	....
Potato, white	3.815	1.547	.175	.027	.331	.141	.055	.270	.130	.140	75.63	27.70	47.93	....
Mangel wurzel	10.270	3.870	.714	.131	.358	.224	1.380	.260	.174	.086	165.76	69.67	96.09	....
Beet pulp	3.216	.347	.185	.729	.283	.138	.048	.069	.006	.063	76.47	14.37	62.10	....
Clover hay	7.313	1.840	.067	1.236	.292	.190	.259	.183	.080	.103	135.49	30.98	104.51	....
Soy bean hay	8.580	1.774	.145	1.378	.692	.259	.084	.237	.121	.116	177.20	33.79	143.41	....
Cowpea hay	12.030	.873	.722	2.029	1.096	.352	.167	.283	.152	.131	244.85	44.89	199.96	....
Alfalfa hay	6.890	.832	.489	1.130	.400	.298	.161	.238	.122	.116	131.63	38.48	93.15	....
Timothy hay	3.470	.613	.345	.192	.111	.162	.199	.123	.062	.071	49.36	23.62	25.74	....
Millet hay	5.887	1.338	.099	.326	.262	.159	1.230	.173	.072	.101	76.21	24.56	51.65	....
Corn stover	7.007	1.847	.065	.507	.092	.187	.308	.102	.039	.063	82.83	26.93	55.90	....
Bluegrass	5.250	1.405	.141	.336	.240	.334	.234	.242	.142	.100	78.39	43.07	35.32	....
Wheat straw	3.650	.842	.237	.217	.063	.159	.209	.038	.015	.023	47.81	18.25	29.56	....
Agar agar	4.990	.132	.135	.780	.570	2.090	.040	.024	.003	.021	125.28	133.06	.....	7.78

TABLE III—MINERAL ELEMENTS OF LEGUMINOUS SEEDS, NITROGENOUS CONCENTRATES AND ANIMAL PRODUCTS
PARTS PER 100 OF DRY SUBSTANCE.

	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Inorganic phosphorus	Organic phosphorus	C. C. Normal Solution per 100 Grams			
											Total base	Total acid	Excess base	Excess acid
Soy beans	5.532	2.095	.380	.230	.244	.444	.025	.649	.017	.632	101.52	70.28	31.24	....
Navy beans	4.420	1.390	.086	.235	.206	.224	.047	.429	.088	.341	67.87	42.96	24.91	....
Cowpeas	4.302	1.636	.189	.117	.243	.280	.047	.532	.023	.509	75.67	53.08	22.59	....
Peanuts	2.538	.061	.563	.068	.180	.254	.024	.399	.049	.350	44.12	42.23	1.89	....
Linseed oil meal	6.463	1.224	.282	.403	.544	.455	.095	.786	...	....	109.07	81.78	27.29	....
Cottonseed meal	7.629	1.811	.283	.291	.599	.536	.042	1.479	.078	1.401	122.28	130.01	.....	7.73
Milk, skim	7.168	1.272	.488	1.336	.146	.357	.953	.979	.551	.428	132.26	112.35	19.91	....
Whey	9.278	2.762	.459	.721	.138	.139	1.948	.640	.402	.238	137.71	104.90	32.81	....
Mutton	2.386	.624	.214	.006	.062	.607	.235	.474	.230	.244	30.66	75.02	.....	44.36
Eggs	3.463	.206	.389	.250	.059	.762	.621	.856	trace	.856	39.42	120.28	.....	80.86
Tankage	17.050	.601	1.830	3.242	.159	.669	2.687	1.789	....	....	269.49	232.92	36.57	....
"Banner" bone flour	100.000	.065	.091	23.990	1.160	....	....	14.940	14.940	....	....	......	.....	....
Blood, swine	4.740	1.040	1.370	.031	.028	.647	1.200	2.800	.076	.204	89.85	92.27	....	2.42
"Black albumen"	4.640	.027	1.247	.039	.011	.820	1.550	.122	.037	.085	63.65	102.74	.....	39.09

TABLE IV—MINERAL ELEMENTS OF WHEATS VARIOUSLY FERTILIZED—PARTS PER 100 OF DRY SUBSTANCE

Description	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Inorganic phosphorus	Organic phosphorus
1 Unfertilized	1.87	.523	.122	.051	.153	.243	.069	.403	.0229	.380
2 Phosphorus	1.82	.561	.127	.055	.149	.224	.073	.406	.0219	.384
3 Potassium	1.73	.497	.135	.047	.152	.237	.112	.37	.0192	.351
4 Unfertilized	1.71	.442	.144	.049	.150	.256	.100	.357	.0181	.339
5 Nitrogen	1.73	.467	.147	.055	.154	.253	.096	.349	.0202	.329
6 Nitrogen; phosphorus	1.75	.467	.139	.057	.149	.243	.085	.358	.0186	.339
7 Unfertilized	1.80	.473	.113	.056	.152	.248	.102	.356	.0208	.335
8 Phosphorus; potassium	1.72	.443	.157	.044	.145	.213	.067	.372	.0179	.354
9 Nitrogen; potassium	1.61	.465	.136	.043	.139	.258	.100	.337	.0185	.318
10 Unfertilized	1.67	.459	.128	.052	.144	.245	.091	.340	.0179	.322
11 Nitrogen; phosphorus; potassium	1.78	.449	.154	.046	.150	.228	.080	.395	.0207	.374
12 Nitrogen; phosphorus; potassium	1.77	.456	.128	.048	.149	.228	.079	.388	.0176	.370
13 Unfertilized	1.82	.451	.168	.053	.149	.241	.090	.359	.0170	.342

TABLE V—ORGANIC AND MINERAL ANALYSES OF FOODS—CEREAL PRODUCTS—PARTS PER 100 OF FRESH SUBSTANCE.

Description	Moisture	Protein (Nx6.25)	Nitrogen free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
Wheat	12.31	10.31	69.59	1.54	2.82	1.64	.520	.031	.050	.130	.198	.084	.373
Wheat flour	13.92	9.74	74.67	1.25	.25	.165	.050	.110	.019	.016	.145	.070	.088
White bread	34.62	9.22	53.58	1.19	.28	1.11	.102	.381	.025	.003	.129	.626	.088
Wheat bran	10.02	15.75	55.30	4.26	8.62	6.06	1.320	.201	.125	.531	.267	.090	1.110
Wheat middlings	11.02	18.84	54.94	5.11	5.97	4.12	1.021	.165	.096	.383	.234	.025	.876
Wheat germ	8.50	29.44	44.37	10.07	2.91	4.71	.296	.721	.071	.340	.325	.070	1.050
Wheat gluten	8.42	80.88	9.15	.65	.19	.71	.007	.028	.078	.045	.920	.050	.200
Red dog flour	10.52	18.50	58.20	5.87	3.19	3.72	.380	.660	.120	.290	.280	.140	.830
Corn	14.24	8.69	69.11	4.03	2.72	1.21	.340	.026	.012	.108	.147	.063	.260
Corn meal, bolted	13.52	8.52	72.96	3.27	1.04	.69	.166	.098	.013	.106	.106	.061	.229
Corn bran	11.00	5.25	66.26	3.10	13.21	1.18	.365	.000	.027	.078	.110	.046	.139
Pearl hominy	11.90	6.88	78.77	1.46	.46	.53	.135	.000	.004	.032	.160	.046	.098
Gluten feed	7.99	27.50	48.86	3.64	8.83	3.18	.250	.424	.247	.220	.585	.090	.542
Distiller's grains, corn	7.71	32.06	37.52	8.90	12.43	1.38	.013	.142	.043	.050	.470	.060	.290
Distiller's grains, rye	8.33	29.25	36.93	6.76	15.34	3.39	.041	.071	.130	.179	.374	.026	.420
Brewer's grains	6.88	19.69	50.18	5.74	14.76	2.75	.172	.259	.157	.160	.390	.058	.468
Malt sprouts	7.46	24.75	45.53	2.10	14.46	5.70	.203	1.350	.147	.180	.800	.360	.690
Oats	8.89	10.88	60.09	4.28	12.48	3.38	.419	.168	.102	.118	.195	.070	.395
Kaffir corn	11.89	10.56	70.91	3.58	1.88	1.18	.254	.058	.012	.125	.164	.104	.239
Rice	10.15	6.48	82.26	.36	.47	.28	.036	.029	.008	.025	.102	.036	.093
Rice polish	11.13	12.48	54.29	11.77	3.20	7.13	1.137	.110	.027	.659	.168	.134	1.497

TABLE VI—ORGANIC AND MINERAL ANALYSES OF FOODS—FRUITS, VEGETABLES AND ROUGHAGE—PARTS PER 100 OF FRESH SUBSTANCE

Description	Moisture	Protein (Nx6.25)	Nitrogen free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
Apple	85.25	.24	13.52	.10	.63	.27	.118	.010	.004	.005	.006	.005	.009
Prune, dried	24.53	2.78	66.67	1.26	1.61	2.15	1.017	.034	.057	.042	.050	.038	.083
Banana	72.63	1.13	24.79	.36	.29	.80	.353	.066	.010	.035	.006	.115	.033
Date, dried	15.44	2.26	77.44	.91	2.32	1.62	.564	.097	.071	.073	.074	.241	.065
Onion	87.29	1.64	9.41	.33	.79	.55	.183	.012	.033	.017	.076	.023	.041
Cabbage	93.05	1.16	4.80	.25	.31	.50	.173	.002	.041	.015	.063	.017	.018
Potato, sweet	73.34	1.28	23.35	.39	.80	.84	.322	.016	.022	.057	.031	.018	.050
Potato, white	82.42	1.97	14.57	.09	.29	.67	.272	.031	.005	.068	.025	.010	.047
Mangel wurzel	88.54	1.68	7.69	.11	.80	1.18	.444	.082	015	.041	.026	.158	.030
Beet pulp, dried	9.53	8.25	59.29	.77	19.25	2.91	.314	.167	.660	.256	.125	.043	.062
Clover hay	7.57	13.00	40.74	3.06	28.87	6.76	1.701	.062	1.142	.270	.176	.239	.169
Soy bean hay	10.61	17.09	36.57	2.47	25.59	7.67	1.586	.130	1.232	.619	.231	.075	.212
Cowpea hay	10.62	22 25	33.64	3.03	19.70	10.76	.780	.646	1.814	.980	.315	.149	.253
Alfalfa hay	7.42	14.41	40.44	1.87	29.48	6.38	.770	.453	1.046	.370	.276	.149	.221
Timothy hay	8.06	5.34	48.13	2.29	32.98	3.20	.564	.317	.177	.102	.149	.183	.113
Millet hay	4.89	6.00	47.56	2.89	33.06	5.60	1.273	.094	.310	.249	.151	.117	.165
Corn stover	6.96	5.48	46.88	1.39	32.77	6.52	1.718	.061	.472	.086	.174	.287	.095
Bluegrass hay	8.21	9.10	40.97	2.89	34.01	4.82	1.290	.129	.308	.220	.307	.215	.222
Wheat straw	5.48	1.75	45.13	1.71	42.48	3.45	.796	.224	.205	.060	.150	.198	.036
Agar agar, dried	15.29	1.88	77.34	.37	.89	4.23	.112	.114	.660	.483	1.770	.034	.020

NOTE—The high protein contents of soy bean hay and cowpea hay as above reported are due in part to the facts that these samples were a little less advanced in maturity than as usually cut for hay and were dried in the laboratory without loss of parts.

TABLE VII—ORGANIC AND MINERAL ANALYSES OF FOODS—LEGUMINOUS SEEDS, NITROGENOUS CONCENTRATES AND ANIMAL PRODUCTS
PARTS PER 100 OF FRESH SUBSTANCE.

Description	Moisture	Protein (Nx6.25)	Nitrogen free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
Soy beans	8.63	39.41	22.54	19.27	5.09	5.06	1.913	.343	.210	.223	.406	.024	.592
Navy beans	14.49	22.23	53.13	1.77	4.60	3.78	1.186	.074	.201	.176	.192	.040	.367
Cowpeas	14.24	22.14	52.94	1.33	5.66	3.69	1.403	.162	.100	.208	.240	.040	.456
Peanuts, roasted	2.71	27.41	17.32	47.95	2.14	2.47	.069	.548	.066	.175	.247	.023	.388
Linseed oilmeal	10.34	35.51	30.91	6.24	11.20	5.80	1.098	.253	.362	.488	.408	.065	.705
Cottonseed meal	8.58	35.88	30.27	11.14	7.15	6.98	1.656	.259	.266	.548	.490	.038	1.352
Milk, skim	90.41	3.21	5.52	.18	....	.69	.122	.047	.128	.014	.034	.091	.094
Whey	93.96	.79	4.69	.01	....	.56	.167	.028	.044	.008	.008	.118	.039
Mutton	61.67	17.18	....	20.26	....	.92	.239	.062	.002	.024	.233	.090	.182
Eggs	73.22	12.93	....	10.21	....	.93	.065	.104	.067	.016	.204	.166	.229
Tankage, digester	9.06	58.59	....	9.29	4.36	15.51	.547	1.664	2.948	.145	.608	2.444	1.627
"Banner" bone flour	....	.....	....	....	....	....	.065	.091	23.990	1.160	....	.....	14.940
Blood, swine	78.82	20.69	....	.27	....	1.00	.220	.290	.007	.006	.137	.250	.059
"Black albumen"	10.76	82.13	....	1.02	....	4.14	.240	1.247	.035	.010	.730	1.380	.109

NOTICE

The following publications of this Station have not been sent to the entire mailing list, because of the technical character of some of them and of the limited areas in which others are likely to be found interesting. Any of these publications, however, will be sent free to any address on application. Address, EXPERIMENT STATION, Wooster, Ohio.

BULLETINS PUBLISHED LESS THAN FULL EDITION

Bulletin 234—Flour Mill Fumigation, by W. H. Goodwin, January, 1912.

Bulletin 238—Tobacco Culture in Ohio, by A. D. Selby and True Houser, March, 1912.

Bulletin 239—Tobacco: Breeding Cigar Filler in Ohio, by A. D. Selby and True Houser, April, 1912.

Bulletin 244—Sweet Clover, by W. A. Lloyd, June, 1912.

Bulletin 247—Nitrogen and Mineral Constituents of the Alfalfa Plant, by J. W. Ames and Geo. E. Boltz, June, 1912.

Bulletin 255—Mineral and Organic Analyses of Foods, by E. B. Forbes, January, 1913.

Bulletin 256—The Miami County Experiment Farm; Second Annual Report for 1912, February, 1913.

Bulletin 258—The Paulding County Experiment Farm; Second Annual Report for 1912, February, 1913.

Circular 124—Horticultural Information, May, 1912.

THE MIAMI COUNTY EXPERIMENT FARM

SECOND ANNUAL REPORT, FOR 1912

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., FEBRUARY, 1913.

BULLETIN 256

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

OHIO AGRICULTURAL EXPERIMENT STATION

BOARD OF CONTROL

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 257 FEBRUARY, 1913.

OATS

COMPARISON OF VARIETIES, FERTILIZATION, PREPARATION OF SEED BED, TIME OF SEEDING, RATE OF SEEDING, QUALITY OF SEED, IMPORTED vs. HOME-GROWN SEED, PROTEIN CONTENT, BARLEY AND OTHER SPRING CROPS

C. G. WILLIAMS AND F. A. WELTON

Twenty years have now elapsed since the Ohio Station was moved to its present site near Wooster. Each season during that time many experiments with oats have been conducted. The reports of the published results may be found in the following:

Bulletin No. 57 issued in December, 1894.
Bulletin No. 67 issued in February, 1896.
Bulletin No. 101 issued in March, 1899.
Bulletin No. 138 issued in March, 1903.
Circular No. 88 issued in February, 1909.

This bulletin brings the report of this line of the Station's work to the close of the season of 1912. In it are given data regarding varieties, fertilization, preparation of seed bed, time and rate of seeding, size and source of seed, protein content, and tests with a few varieties of barley and other spring crops.

On account of variations in seasons, the results obtained in any one year are less valuable than are those representing the average of a series of years, and, generally speaking, the longer the average the more valuable the results. Therefore, as far as possible, in this bulletin the new data have been averaged with the old, i. e. with that reported in Circular 88 and Bulletin 138, thus bestowing a value which time alone can give.

FACTS ABOUT PAULDING COUNTY

Population, 1910, 22,730.
Number of farms, 2,840.
Average size of farms (acres), 90
Percent operated by tenants, 34.3.
Yield of corn per acre (10-year average, 1900-1909), 40.9
Size of Experiment Farm (acres), 92.
Cost of Experiment Farm, per acre $176.85.

LINES OF WORK OF COUNTY EXPERIMENT FARM

1. Value of the different methods of crop rotation.
2. Use of manure, fertilizers, catch crops, and lime.
3. Determining varieties of farm crops best suited to the county.
4. Introducing pure seed of the most suitable varieties.
5. Demonstrating the value of promising new crops.
6. Methods of growing alfalfa and soybeans.
7. Field crops demonstrations.
8. Planting and caring for the young orchard.
9. Pruning, fertilizing, and spraying the farm orchard.
10. Control of plant diseases and noxious weeds.
11. Control of injurious insects.
12. Methods of farm management applicable to the county.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 258 FEBRUARY, 1913.

SECOND ANNUAL REPORT OF PAULDING COUNTY EXPERIMENT FARM

By CHAS. McINTIRE, Agent in Charge

In February, 1912, the first annual itemized financial report was rendered to the Board of County Commissioners. This report, which is on file for public inspection at the office of the County Auditor, also includes a report of all improvements and work done upon the farm during the first season. Bulletin 241, of the Ohio Experiment Station, gives the plan of management, as approved by the County Agricultural Society, together with results of a few experiments conducted during the first season, and constitutes the first annual report of the farm. During 1912, experiments were begun along the following lines.

SOIL FERTILITY

Paulding is ranked among the highly productive counties of the state, and if the Experiment Farm can cause the adoption of policies by which this production may be indefinitely maintained, as much good will be accomplished as by demonstrating methods of restoring impoverished lands in counties where production is very low.

The productive power of rich lands is easily maintained; while the restoration of impoverished lands is a most difficult task. At the Experiment Farm several methods of maintaining and increasing crop yields will be demonstrated, as follows:

CROP ROTATION AND FERTILITY TESTS

The continuous cropping of the land with the same crop is largely responsible for the impoverished condition of many farms today. A systematic rotation in which one or two leguminous crops

are grown every three or four years will do much towards the maintenance and improvement of the land. Such a rotation provides sods for turning down, and means that humus and nitrogen will be provided.

Crop rotation has been found to be so very essential to successful farming that it has become indispensable. This is especially true with rented farms where but little livestock is kept. Land owners having farms to rent should for the sake of all concerned require a systematic rotation of crops to be followed. Such a rotation will be good for the land, good for the tenant, and good for the land owner.

Just what crops should be grown, what rotations will pay best and be best for the land is a very important matter and should be carefully considered by every farmer and land owner. In order to help answer this question the Experiment Farm has established three distinct rotations, as follows:

Rotation No. 1. Corn, oats, wheat, clover.
Rotation No. 2. Corn, soybeans, wheat, clover.
Rotation No. 3. Sugar beets, oats, clover.

A careful record of all crop yields will be kept and the advantage and disadvantage of each rotation pointed out.

COMMERCIAL FERTILIZERS

The use of chemical fertilizers in Paulding county is still in its infancy and no marked results are expected as yet. Under present methods of farming, however, the day is not far distant when commercial fertilizers will be used extensively here, as is now being done in all of the older counties of the state. Assuming that the use of purchased plant food will be adopted in the county sooner or later, the Experiment Farm has already taken up the investigation of the subject.

While each of the rotations referred to elsewhere will be conducted without any fertilization whatever, arrangements have also been made to ascertain the value of manure, lime, commercial fertilizers, and catch crops, in connection with the growing of all crops. In the beets-oats-clover rotation the fertilizers are applied to the beet crop, only, and the increase in the oats and clover as well as in the beets will be credited to the fertilizers. The fertilizing materials used in this test are easily obtainable and the results should be carefully studied by all beet growers.

While the soil upon which these soil fertility tests are made is quite uniform and will some day be highly satisfactory for the work, the results thus far have been irregular; this is especially true with the beet crop, owing largely to the fact that the field is infested with wire worms which prevent the securing of a uniform stand.

No marked results were obtained from any of the fertilizing materials used during 1912, but the work will be continued, and by the time the use of commercial fertilizers is taken up by the farmers of the county, the Experiment Farm will have established some valuable facts.

Table I gives the plan of treatment and the results of the manure and fertilizer experiments with sugar beets for 1912. The lack of uniformity was largely due to the injury of the stand by wire worms.

TABLE I: FERTILIZERS ON SUGAR BEETS AT PAULDING COUNTY EXPERIMENT FARM, 1912.

Rotation 3, Beets-oats-clover, Block K

Plot No.	Treatment per acre	Yield per acre tons	Increase or decrease (—) per acre tons	Value of increase	Cost of treatment	Net gain or loss (—)	Percent of sugar	Percent of purity
1	None	13.85	....	$....	$...	$....	....	82.9
2	Acid phosphate, 600 lbs.	13.00	—.26	—1 30	4.80	—6 10	12.8	81.2
3	Muriate of potash, 200 lbs.	11.35	—1.39	—6.50	5.00	—11.50	12.6	80.9
4	None	12.075	....	....	....	....	12.4	not given
5	Nitrate of soda, 200 lbs.	13.85	1.95	9.75	6.00	3.75	12.8	85.5
6	Acid phosphate, 600 lbs Nitrate of soda, 200 lb3.	12.025	.32	1.60	10.80	—9.20	13.2	86.5
7	None	11.525	....	....	....	....	13.1	86.8
8	Acid phosphate 600 lbs. Muriate of potash, 200 lbs.	10.55	—.52	—2.60	9.80	—12.40	12.7	86.0
9	Muriate of potash, 200 lbs Nitrate of soda, 200 lbs.	13.50	2.89	14.45	11.00	3.45	13.6	83.0
10	None	10.15	....	....	....	....	13.2	86.5
11	Acid phosphate, 600 lbs. Muriate of potash, 200 lbs. Nitrate of soda, 200 lbs	15.75	4.88	24.40	15.80	8.60	12.8	84.0
12	Acid phosphate, 600 lbs. Muriate of potash, 200 lbs Nitrate of soda, 200 lbs Sugar factory lime, 2 tons.	14.15	2.56	12.80	18.80	—6.00	12.8	85.5
13	None	12.30	....	....	....	....	13.5	84.2
14	Sugar factory lime, 2 tons.	11.575	—.55	—2.75	3.00	—5.75	12.7	83.9
15	Floats, 1200	12.45	.60	3.00	5.80	—2.80	13.5	83.3
16	None	11.775	....	....	....	....	13.4	83.2
17	Yard manure, 10 tons	12.10	.56	2.80	2.50	0.30	12.8	84.5
18	Fresh manure, 10 tons	12.975	1.66	8.30	2.50	5.80	13.0	83.7
19	None	11.075	....	....	....	....	13.2	85.0
20	Fresh manure, 10 tons Sugar factory lime, 2 tons	12.975	2.13	10.65	5.50	5.15	14.2	84.9
21	Fresh manure, 10 tons Acid phosphate, 300 lbs	13.975	3.36	16.80	4.90	11.90	13.6	84.8
22	None	......	....	....	....	....	....	....
	Average unfertilized results	11.82	....	....	....	....	13.1	84.8

In calculating the increase in these tables it is assumed that variations in the soil are progressive, and that the yields of beets on Plots 1 and 4 being 13.85 and 12.07 tons, respectively, Plots 2 and 3 should have yielded 13.26 and 12.66 tons, respectively, if left unfertilized. While of course this regular variation will not always occur, experience has shown that in general this method of computation most nearly approximates the true results.

The land for the beet crop has been plowed 7 inches deep in the fall and the manure has been applied in the spring. The acid phosphate used to reinforce the manure and all other fertilizers have been applied with the grain fertilizer drill, and the lime has been spread by hand before spreading the manure.

In computing cost of treatment, manure is rated at 25 cents per ton, to cover the greater cost of applying manure than fertilizers. The cost of the manure, as it lies in the barnyard, is left for the farmer to compute. The lime is rated at $1.50 per ton, to cover cost of hauling from sugar factory. No charge is made for it there.

The crop on Plots 22 to 28 was so injured by wire worms as to make comparison impossible. Plot 1 has been affected by the subsoil thrown out from an open ditch, 25 feet away.

For the determinations of sugar and purity the Station is indebted to the courtesy of the German-American Sugar Company, of Paulding.

The results shown in Table I are very irregular, as is always expected in a first experiment on previously untreated land. These results would seem to indicate that acid phosphate has been a detriment to the crop, and that practically all the increase has come from nitrate of soda, but that it would be very unwise to accept this point as demonstrated is shown by the experiments at the Central Station at Wooster, in which different fertilizing materials have been used on crops grown in a 5-year rotation since 1894. The following table shows the increase or decrease of wheat from a few of these different treatments on the first crop, harvested in 1894, and on the average of the 19 crops harvested throughout the period.

TABLE II: INCREASE OR DECREASE IN YIELD OF WHEAT PER ACRE, CROP OF 1894 AND AVERAGE OF 19 CROPS, 1894-1912.

Plot No.	Treatment	Increase (+) or decrease (−) per acre	
		1894	19 years 1894-1912
		Bus.	Bus.
2	Acid phosphate	−2.80	+7.88
3	Muriate of potash	+5.63	+1.19
5	Nitrate of soda	−1.22	+1.88
6	Acid phosphate and nitrate of soda	−4.65	+13.13
8	Acid phosphate and muriate of potash	−1.11	+9.02
9	Nitrate of soda and muriate of potash	+3.53	+2.67
11	Acid phosphate, nitrate of soda and muriate of potash	−0.42	+15.85

If we had accepted the results of the first test as final we would have assumed that potassium was the only fertilizing element required by this soil, and that phosphorus was a detriment instead of a help—an assumption the exact opposite of the truth.

In the light of later and more extended investigations it appears that the results of 1894 were due to one of the most valuable attributes of acid phosphate—its tendency to hasten maturity. Ordinarily this tendency is a great advantage, but occasionally it is a disadvantage.

Table III gives the yields of the oats following the beets in this rotation. Beets were grown in this test in 1911, but the crop wss lost because of the excessive rains at the time of harvesting. In the test of 1912 the crop was so injured by wire worms on Plots 17 to 28, inclusive, that no comparison can be made.

TABLE III: RESIDUAL EFFECT ON OATS OF FERTILIZERS APPLIED TO SUGAR BEETS AT PAULDING COUNTY EXPERIMENT FARM, 1912.

Rotation 3, Beets-oats-clover, Block I.

Plot No.	Treatment per acre for the beet crop	Yield per acre		Increase or decrease (—) per acre		Value of increase
		Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	
1	None....	76.87	5,390	....	.....	$....
2	Acid phosphate, 600 lbs.	64.69	4,180	—10.10	—1,143	—4.17
3	Muriate of potash, 200 lbs.	66.88	5,760	—5.83	504	—1.25
4	None.	70.62	5,190	....	.....	....
5	Nitrate of soda, 200 lbs	68.12	6,670	1.56	1,637	2.10
6	Acid phosphate, 600 lbs. Nitrate of soda, 200 lbs	62.81	4,260	1.31	—616	—.22
7	None.	58.44	4,730	....	.....	....
8	Acid phosphate, 600 lbs. Muriate of potash, 200 lbs.	71.56	5,360	12.70	885	4.69
9	Muriate of potash, 200 lbs. Nitrate of soda, 200 lbs.	65.16	5,790	5.88	1,570	3.33
10	None.	59.69	3,965	....	.....	....
11	Acid phosphate, 600 lbs. Muriate of potash, 200 lbs. Nitrate of soda, 200 lbs.	57.34	5,290	—1.57	1,217	.75
12	Acid phosphate, 600 lbs. Muriate of potash, 200 lbs. Nitrate of soda, 200 lbs. Sugar factory lime, 2 tons	63.75	5,460	5.62	1,279	2.96
13	None.	57.34	5,190	....	.....	....
14	Sugar factory lime, 2 tons.	*	.....	....	.....	....
15	Floats, 1,200 lbs	69.40	5,760	8.82	906	3.55
16	None.	62.19	4,685	....	.....	....
	Average unfertilized yield.	64.19	4,858	....	.....	....

*No record.

THE CEREAL ROTATIONS

These rotations were begun on the east side of the farm in 1911, but the land was found to be so unsuited to the work that it was transferred to the west side in 1912.

The plan of treatment in Rotation I is shown in Table IV and the yield for 1912 in Tables V and VI.

TABLE IV: PLAN OF FERTILIZING IN CEREAL ROTATION No. 1, PAULDING COUNTY EXPERIMENT FARM.

Pounds of fertilizing materials per acre for each crop

Rotation I: Corn, oats, wheat, clover

Plot No.	Acid phosphate	Muriate potash	Nitrate soda	Lime carbonate	Acid phosphate	Muriate potash	Nitrate soda	Acid phosphate	Muriate potash	Nitrate soda
	On Corn				On Oats			On Wheat		
1	...		..	......	...	..	..	...	..	..
2	200	..	..	......	100	..	..	200	..	..
3	200	50	..	......	100	20	..	200	20	..
4	...	..	..	......	...	..	..	...	..	..
5	200	50	50	......	100	20	30	200	20	80
6	200	50	50	4,000	100	20	30	200	20	80
7	...	..	..	....	...	..	..	...	..	..
8	Manure, 8 tons		..	......	...	..	..	200	50	50
9	Manure, 8 tons, phosphated				...	..	..	200	50	50
10	...	..	..	......	...	..	..	..	..	..

TABLE V: FERTILIZERS ON CORN AT PAULDING COUNTY EXPERIMENT FARM, 1912

Rotation 1, Corn-oats-wheat-clover, Block B.

Plot No.	Treatment per acre	Yield per acre		Increase or decrease (—) per acre		Value of increase	Cost of treatment	Net gain or loss (—)
		Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.			
1	None	65.00	4,500	....	..	$....	$....	$...
2	Acid phosphate, 200 lbs	70.00	4,400	3.95	—50	1.51	1.60	—0.09
3	Acid phosphate, 200 lbs; Muriate of potash, 50 lbs	63.14	4,650	—3.96	250	—1.21	2.85	—4.06
4	None	68.14	4,350	....	...	...	....	....
5	Acid phosphate, 200 lbs; Muriate of potash, 50 lbs; Nitrate of soda, 50 lbs	67.86	4,250	1.48	83	0.72	4.35	—3.63
6	Acid phosphate, 200 lbs; Muriate of potash, 50 lbs; Nitrate of soda, 50 lbs; Sugar factory lime, 2 tons	56.50	3,950	—8.12	—34	—3.30	5.85	—9.15
7	None	62.86	3,800	....	...	....	....	....
8	Fresh manure,[1] 8 tons	63.00	4,100	1.48	—50	0.52	2.00	—2.50
9	Fresh manure, 8 tons[2]; Acid phosphate, 320 lbs	54.43	4,600	—5.75	400	—1.70	3.60	—5.30
10	None	58.85	3,950	....	....	....	....	....
	Average unfertilized yield	63.71	4,150	....	...	...	....	...

[1]The manure has been taken from horse stables after a short exposure to weather.
[2]The acid phosphate has not been mixed with the manure, but has been applied later with fertilizer drill. The manure is rated at 25 cents per ton, to an extra cost of application over that of fertilizer.

TABLE VI: FERTILIZERS ON OATS AT PAULDING COUNTY EXPERIMENT FARM, 1912

Rotation I, Corn-oats-wheat-clover, Block A

Plot No.	Treatment per acre	Yield per acre		Increase or decrease (—) per acre		Value of increase	Cost of treatment	Net gain or loss (—)
		Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.			
1	None	53.91	4,450	....	...	$....	$....	$...
2	Acid phosphate, 100 lbs	57.19	4,020	2.81	—248	0.59	0.80	—0.21
3	Acid phosphate, 100 lbs; Muriate of potash, 20 lbs	60.47	3,675	5.62	—411	1.27	1.30	—0.03
4	None	55.31	3,905	...	...	....	....	....
5	Acid phosphate, 100 lbs; Muriate of potash, 20 lbs; Nitrate of soda, 30 lbs	65.94	3,715	10.79	—37	3.20	2.20	1.00
6	Acid phosphate, 100 lbs; Muriate of potash, 20 lbs; Nitrate of soda, 30 lbs	64.37	3,470	9.38	—130	2.68	2.20	0.48
7	None	54.84	3,445	....	...	....	....	....
8	To follow 8 tons manure on corn	52.34	3,100	....	...	....	....	....
9	To follow 8 tons phosphated manure on corn	49.68	2,935	....	...	....	....	....
10	None	55.94	3,335	....	...	....	...	....
	Average unfertilized yield	55.00	3,784	....	...	....	....	....

CUMULATIVE EFFECT OF FERTILIZERS

The experience of the Experiment Station has been that the full effect of a fertilizer is never realized in the crop to which it is applied, but that when fertilizers or manures are used in a systematic rotation of crops, there will usually be a material increase in effectiveness for a considerable period.

TABLE VII: FERTILIZERS AND MANURE ON CROPS GROWN IN ROTATION AT WOOSTER. TOTAL FERTILIZING MATERIALS AND THEIR COST, AND TOTAL AND NET VALUE OF INCREASE PRODUCED FOR 5-YEAR PERIODS AND FOR 18 YEARS, ALL CALCULATED FOR ONE ROTATION OF 5 YEARS.

Plot No.	Fertilizing materials in pounds per acre for each rotation	Cost of fertilizers for each rotation	Average value of total increase per acre for each rotation				Net gain or loss (−) from fertilizers for each rotation				
			First 5-years	Second 5-years	Third 5-years	18-year average Total	First 5-years	Second 5-years	Third 5-years	18-year average Net	
2	Acid phosphate, 320	$ 2.60	$ 8.50	$ 17.37	$ 24.32	$ 16.53	$ 5.90	$ 14.77	$ 21.72	$ 13.93	2
3	Muriate potash, 260	6.50	5.19	4.67	9.17	6.21	−1.31	−1.83	2.67	−0.29	3
5	Nitrate soda, 440; dried blood, 50	14.40	4.70	10.47	9.30	8.31	−9.70	−4.00	−5.37	−6.09	5
6	Acid phosphate, 320; nitrate soda, 440; dried blood, 50	17.00	19.09	35.27	39.75	30.04	2.09	18.27	22.75	13.04	6
8	Acid phosphate, 320; muriate potash, 260	9.10	14.40	24.37	33.51	24.48	5.30	15.27	24.41	15.38	8
9	Muriate potash, 260; nitrate soda, 440; dried blood, 50	20.90	5.85	11.35	13.23	11.08	−15.05	−9.55	−6.67	−8.82	9
11	Acid phos., 320; mur. potash, 260; nit. soda, 440; dried blood, 50	23.50	26.39	42.43	49.96	39.14	2.80	18.93	26.46	15.64	11
12	" " 320; " " 260; " " 680; " " 50	30.70	26.16	45.53	48.24	39.71	−4.54	14.83	17.54	9.01	12
14	" " 240; " " 180; " " 280; " " 50	16.05	21.37	32.91	37.33	30.59	5.32	15.86	21.28	14.54	14
15	" " 160; " " 100; " " 120; " " 50	8.60	13.89	22.86	27.13	22.08	5.29	14.26	18.53	13.48	15
17	" " 480, " " 260; " " 220; " " 25	17.60	15.74	36.61	46.28	34.92	−1.86	19.01	28.68	17.32	17
18	Yard manure, 16 tons	?	19.82	34.24	55.94	39.32	?	?	?	?	18
20	Yard manure, 8 tons	?	13.02	21.28	35.36	25.34	?	?	?	?	20
21	Same elements as 17, but nitrogen in oilmeal	17.60	20.43	36.25	42.24	33.49	2.83	18.65	24.64	15.89	21
23	" " " 17, " " " dried blood	17.60	19.09	34.37	39.28	31.83	1.49	16.77	21.68	14.23	23
24	" " " 17, " " " sulphate ammonia	17.60	20.70	32.77	38.71	31.83	3.10	14.77	21.11	14.23	24
26	" " " 11, " phosphorus in bonemeal	23.50	20.89	36.17	42.55	32.86	−2.61	12.67	19.05	9.36	26
27	" " " 11, " " " dissolved boneblack*	23.50	19.86	39.88	42.08	33.71	−3.64	16.38	18.58	10.21	27
29	" " " 11, " " " basic slag	23.50	21.91	39.32	39.04	33.56	−1.59	15.82	15.54	10.06	29
30	" " " 17, " nitrogen in tankage	**17.60	13.74	30.51	41.62	30.36	...	12.90	24.02	12.76	30

The nearest practicable approach to a common denominator for the various kinds of produce grown in this rotation is their market value, and in Table VI the results of the tests are arranged on this basis for three 5-year periods and for the entire 18 years, corn being rated at 40 cents per bushel, oats at 30 cents, wheat at 80 cents, hay at $8.00 per ton, stover at $3.00 and straw at $2.00; valuations much below present prices for the grains, but not far from the average values during the period of the test.

The fertilizing materials are valued at a fraction over $16.00 per ton for acid phosphate, 2¼ cents per pound for muriate of potash and 3 cents per pound for nitrate of soda; and it is assumed that the cost per pound of the fertilizing elements will be practically the same in the other carriers used on Plots 21 to 30, inclusive.

The table shows that the effectiveness of the fertilizers and manure has increased with each successive period, the greatest relative increase being shown by the manure. Taking the second part of the table, giving the net gain after deducting the cost of the fertilizers, it will be seen that during the first period eight of the fertilizer applications failed to produce sufficient increase to cover their cost; during the second period three, and during the third period two. Every complete fertilizer has been used with a profit since the first period, but when either nitrate of soda or muriate of potash has been used unaccompanied by some carrier of phosphorus there has been a loss in each period and in the average of the 18 years.

Nevertheless, both nitrogen and potassium are essential to the highest net profit, as shown by comparing Plot 2, receiving phosphorus only, with Plot 8, receiving potassium in addition, and Plot 11, receiving these with nitrogen.

The results of the comparison of different carriers of nitrogen and phosphorus have been discussed in Circular No. 93.

*Previous to 1910. Since 1910 nitrogen in nitrate of lime and phosphorus in acid phosphate.

**Since first period. Smaller application during first period.

This point is demonstrated by the results attained at Wooster, where experiments in the use of fertilizers and manure on crops grown in a 5-year rotation of corn, oats, wheat, clover and timothy have been in progress since 1894. The results of this work are grouped by 5-year periods in Table VII, reproduced from Circular 120.

SOYBEANS

The soybean might well be classed a new crop in Paulding county, and owing to the fact that it is a crop of great value in many sections, it will be given a thorough trial at the Experiment Farm. Owing to frequent failures of clover and the difficulty of getting alfalfa through the winter in this section, the growing of soybeans or some other legume is very important. The soybean is considered a valuable crop for the following reasons:

1. It is well adapted to the soils of the county.
2. Being a legume, it improves the land.
3. It fits well in a four-year rotation of corn, soys, wheat, clover.
4. The stubble make a fine seed bed for wheat.
5. Being a spring crop, it is grown at little risk.
6. It makes excellent hay.
7. The seed makes a very rich feed.
8. It yields more than wheat, and thus far has sold for more than twice as much per bushel.

The day will undoubtedly come when this crop will be grown extensively throughout the county and farmers are advised to begin in a small way to study its growth. A well-fitted seed bed is of first importance. The seed should be drilled shallow, as deep planting with a heavy rain before coming up means a poor stand. Broadcasting is not the thing in Paulding county. Drill in rows 28 to 32 inches apart, using three to four pecks of seed per acre. Seeding should be done the last week of May or first week of June and the crop cultivated about the same as corn or potatoes. When wanted for hay, cut when beans begin to form in the pods. Owing to failure to get a good stand, no variety test was made in 1912.

An experiment with different methods of fertilizing soybeans was conducted during 1912, the plan of which and the results for that season are shown in Table VIII.

TABLE VIII: PLAN OF FERTILIZING IN ROTATION No. 2, PAULDING COUNTY EXPERIMENT FARM, AND YIELD OF SOYBEANS, 1912.

Rotation No. 2, Corn, soybeans, wheat, clover

Plot No.	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Nitrate of soda
	On Corn			On Soybeans			On Wheat		
1	...	..	..	...	..	..	...	..	..
2	200	..	..	100	..	..	200	..	..
3	200	50	..	100	20	..	200	20	..
4	..	..	..	...	..	..	...	..	..
5	200	50	50	100	20	30	200	20	80
6	130	50	20	70	20	10	160	20	20
7	...	..	..	...	..	..	...	..	..
8	160	20	20	100	..	..	170	..	30
9	160	20	20	100	..	..	170	..	30
10	...	..	..	...	..	..	...	..	..

Plot No.	Treatment per acre	Yield per acre Bus.	Increase per acre Bus.	Value of increase	Cost of treatment	Net gain or loss (—)
1	None	19.75	....	$....	$....	$....
2	Acid phosphate, 200 lbs	20.17	0.89	1.78	1.60	0.18
3	Acid phosphate, 200 lbs; Muriate of potash, 50 lbs	22.25	3.44	6.88	2.85	4.03
4	None	18.33	....	....	....	....
5	Acid phosphate, 200 lbs; Muriate of potash, 50 lbs; Nitrate of soda, 50 lbs	22.08	3.55	7.10	4.35	2.75
6	Acid phosphate, 130 lbs; Muriate of potash, 50 lbs; Nitrate of soda, 20 lbs	19.67	0.94	1.88	2.89	—1.01
7	None	18.92	...	....	....	....
8	Acid phosphate, 160 lbs; Muriate of potash, 20 lbs; Nitrate of soda, 20 lbs	21.08	1.72	3.44	2.38	1.06
9	Acid phosphate, 160 lbs; Muriate of potash, 20 lbs; Nitrate of soda, 20 lbs	20.67	0.87	1.74	2.38	—0.64
10	None	20.25	....	....	....	....
	Average unfertilized yield	19.31	....	....	....	....

VARIETY TESTING

Securing proper varieties has much to do with producing maximum yields of all farm crops. One of the leading lines of work of the County Experiment Farm is the testing of varieties and the distribution of seed of the most promising sorts among the farmers of the county. During 1912, variety tests were made with the following crops. For comparison, tests made at Wooster and other test farms are added:

TABLE IX: VARIETY CORN TEST: PAULDING COUNTY, 1912.

Plot No.	Name of variety	Actual yield per acre: Grain Bus.	Actual yield per acre: Stover Lbs.
1	Eichling	67.43	4,450
2	Morisy's Reid's Yellow Dent	78.35	5,700
3	Morisy's Gold Mine	73.50	5,450
5	Wheeler's R. Y. Dent	90.64	6,300
6	Wheeler's Clarage	87.86	5,150
7	Graves' R. Y. Dent	79.43	6,050
8	Cook's 75	82.50	6,050
10	Leaming	87.64	5,400
11	McGrath's Gold Mine	71.21	6,100

SUBSOILING FOR SUGAR BEETS

The following experiment in subsoiling was made this year:

SUBSOILING FOR SUGAR BEETS

Plot No.	Treatment	Yield per acre tons	Percent sugar	Percent purity
1	Ordinary plowing	11.126	13.2	84.4
2	Subsoiled	11.775	14.3	84.6
3	Ordinary plowing	11.300	14.2	83.6
4	Subsoiled	11.050	14.4	85.6
	Average ordinary plowing	11.71	13.7	84.0
	Average subsoiling	11.41	13.9	85.1

The "ordinary plowing" was 7 inches deep. The subsoiling was done by following the ordinary plow with a subsoil loosener, running to the depth of 14 inches.

ORCHARDING

Fruit growing will not be made a leading feature of the Experiment Farm work. It has been found, however, that there is sufficient interest throughout the county in the farm orchard to justify the management in taking up this line of work at the Experiment Farm. The orchard already upon the farm, while not of the best varieties and badly neglected, has during the past two years proven itself well worth preserving and the work of rejuvenation will be taken up the coming spring, when public demonstrations in pruning and spraying will be made.

A new four-acre orchard was planted during the season of 1912. Cultural methods, fertilizing, pruning, spraying, the testing of varieties, and the care of the orchard in general, will be demonstrated. While considerable time will be required before coming into bearing, farmers will be interested in the effect of cultivation and fertilization on the growth of the trees.

VISIT THE FARM

While an annual report will be made, giving details of all work conducted upon the Experiment Farm, nothing will do so much good as, or take the place of, frequent visits to the farm. This affords opportunity to see the crops growing in the field, to study the effect of the different fertilizing materials, to compare the different varieties, etc. "Seeing is believing," and frequent visits to the Experiment Farm will do more to convince the farmer of the value of the experiments than any number of bulletins or publications.

OHIO WEATHER FOR 1912

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., MARCH, 1913.

BULLETIN 259

OHIO AGRICULTURAL EXPERIMENT STATION

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[1]In cooperation with Bureau of Plant Industry, U. S. Department of Agriculture.
[2]In cooperation with Boys' Industrial School. [3]In cooperation with Ohio State Reformatory.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 259 MARCH, 1913.

OHIO WEATHER FOR 1912

BY J. WARRAN SMITH AND C. A. PATTON

EXPLANATORY

BY THE DIRECTOR

The extension of the work of the Experiment Station over the state, through the district and county experiment farms, makes it necessary that its weather records should be state-wide in their application. Hitherto the only attempt at such application has been to give the average rainfall and temperature for the entire state for comparison with the observations taken at the main station at Wooster, but it is now possible, through the cooperation of Prof. J. Warren Smith, Section Director for Ohio of the U. S. Weather Bureau, to supplement these records with a series of diagrammatic maps, showing at a glance the comparative weather conditions for the different sections of the state.

These maps will be followed by the usual summary tables.

Mean Temperature (Normal) January

Figure 1. Normal temperature for January. The figures show the average temperature at the different points for the total length of time covered by the observations. In no case is the period less than 10 years and it may be 50 years or more. At Portsmouth the average is for 81 years and at Marietta 68 years. The figures have been entered to whole numbers and the lines of equal temperature drawn rather freely across the state. The lines are drawn for each two degrees. The warmest part of the state is in the extreme south and the coldest in the northwest. The normal temperature for the State is 28°.

Mean temperature, January, 1912

Figure 2. Average temperature for January, 1912. This was one of the coldest months on record in Ohio. The minimum temperature was close to or below zero from the 4th to 17th. The highest maximum temperature during the month was only 57° at Ironton. This is the lowest maximum for the state since the weather service was established in 1882. The lowest temperature recorded was −37° at Milligan, Perry county, and this is the lowest on record, except −39° at the same station on February 10, 1899. Water pipes were badly frozen, potatoes and other vegetables greatly damaged, peach buds were almost universally killed except on the highest ground in southern counties and on the islands in Lake Erie.

Temperature departures, January, 1912

Below normal Above normal

Figure 3. Departure of the temperature from the normal, January, 1912. The mean temperature for the state was 10.3° below the normal. It averaged 13° a day below the normal in Sandusky county and 12° below at quite a number of stations. There were but few days during the entire month when the temperature was above the normal. From the 4th to 17th, inclusive, there occurred one of the most prolonged spells of severely cold weather ever experienced in Ohio. During the entire time the minimum temperature was below or close to zero, and on the 13th it was over 30° below zero at eight stations in eastern and southern counties. The amount of suffering among the poor in the cities was very great. Several deaths from exposure were reported.

Normal precipitation for January

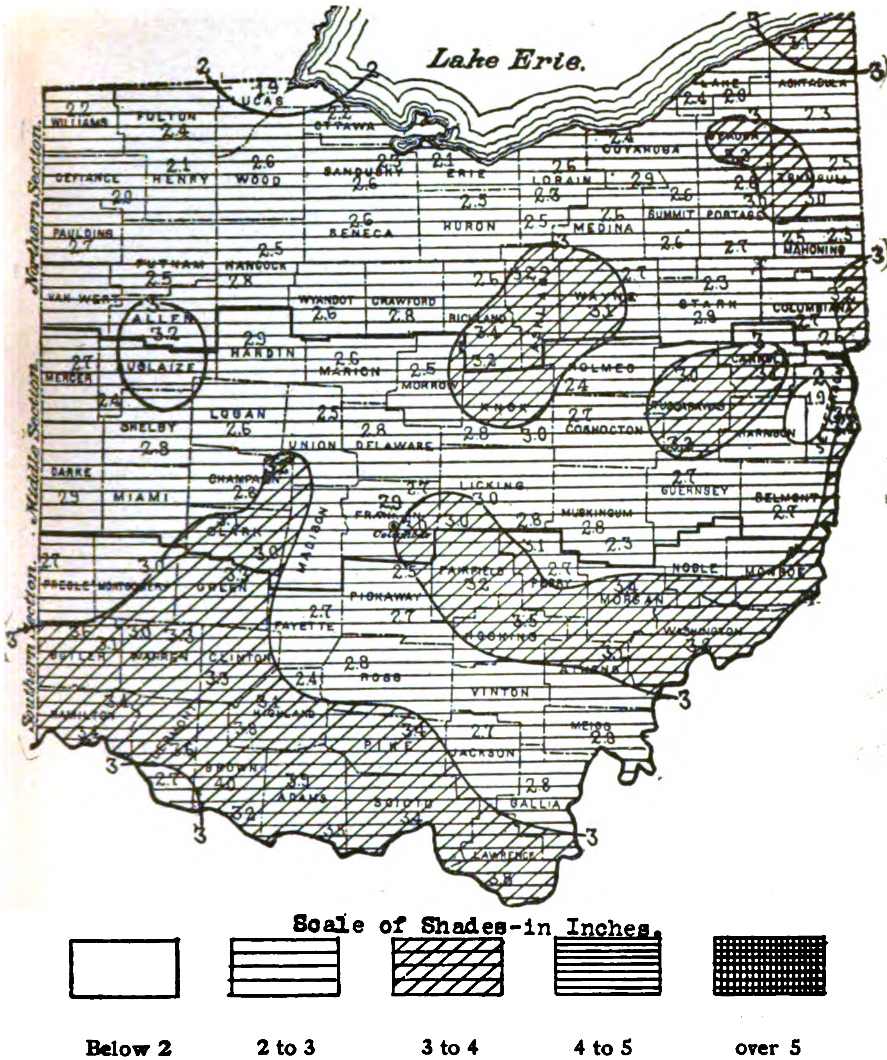


Figure 4. Average precipitation for January. The data are obtained by getting the average at each station for January for all the years that observations have been taken. In each case the record is for 10 years or more, and in the case of Marietta it is for 92 years, Portsmouth 81 years and for Cincinnati 77 years. Equal rainfall lines are then drawn for each inch of precipitation and the areas are shaded as indicated by the key. The precipitation is well distributed over the state. The average for the state for this month is 2.97 inches.

Precipitation, January, 1912

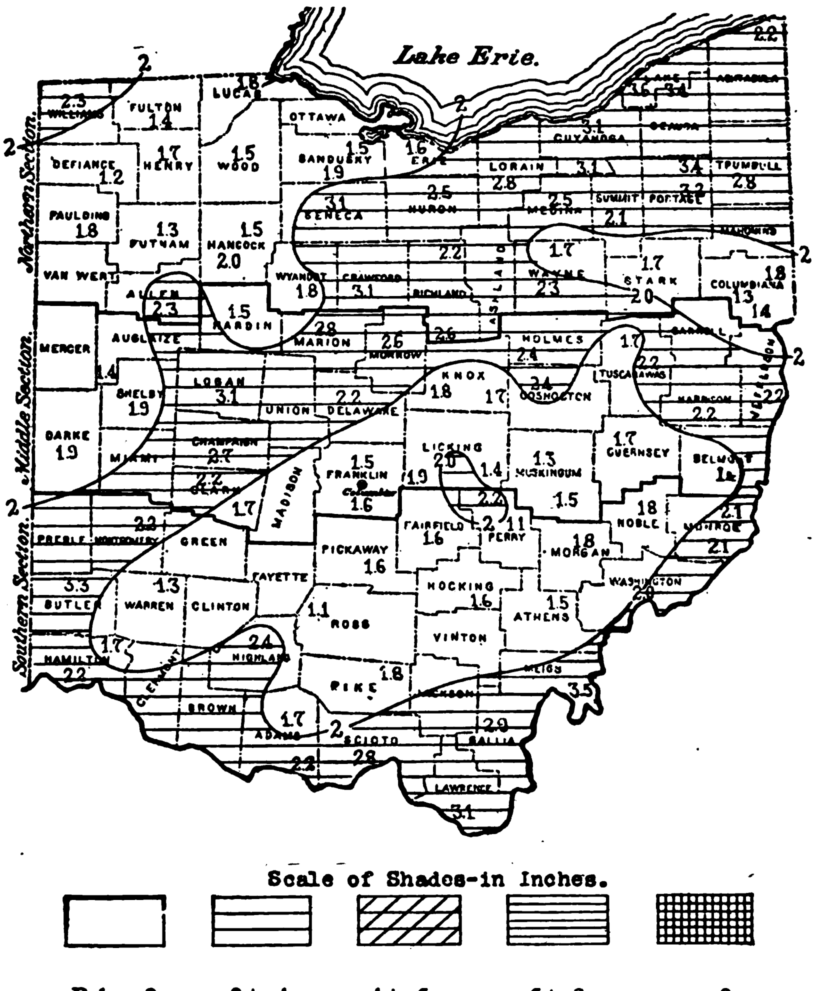


Figure 5. Total precipitation, January, 1912. The rain and melted snow averaged 2.12 inches for the state and was heaviest in the extreme south and in the northeast. No heavy precipitation occurred but rain or snow fell on an unusually large number of days.

Precipitation departures, January, 1912

Scale of Shades.

Below normal Above normal

Figure 6. Departure of the precipitation from the normal, January, 1912. The precipitation was slightly above the normal in a few districts but the average for the state was 0.68 inch below the normal. The streets and roads were very icy during the latter part of the month.

Snowfall, January, 1912

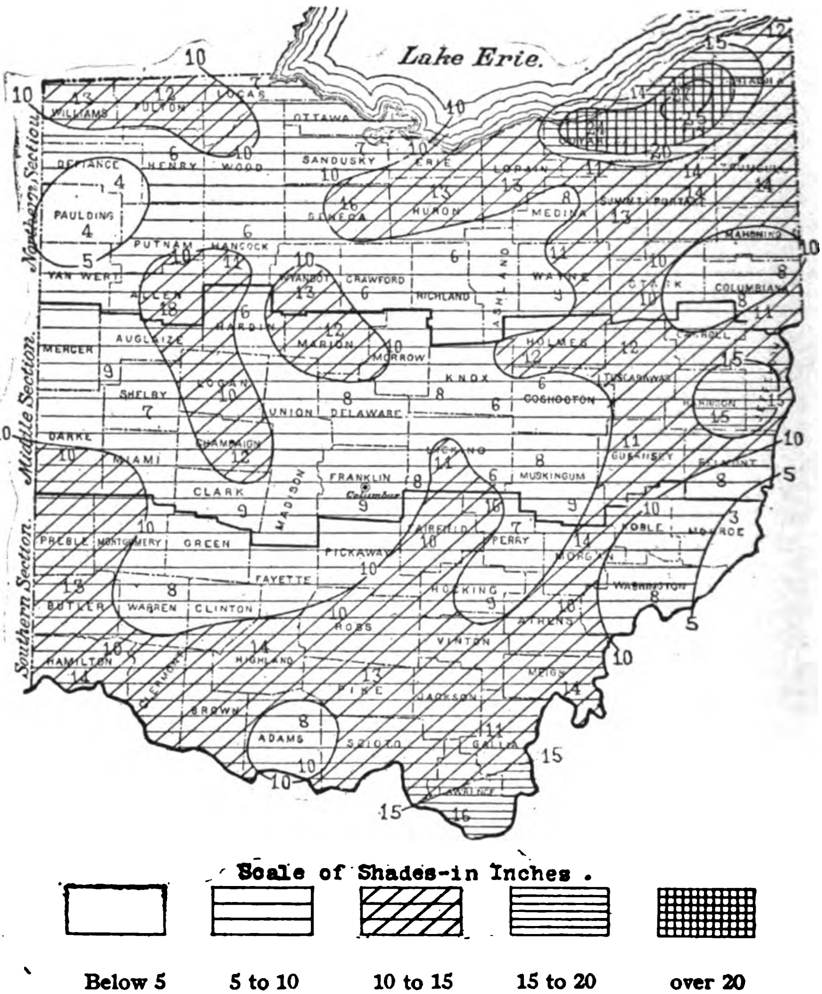


Figure 7. Total snowfall, January, 1912. The snowfall for January was slightly above the normal for this month. Most of the precipitation during the month was in the form of snow, and over most of the state the ground was covered with snow from the 6th to the close of the month.

Mean temperature (normal) February

Figure 8. Normal temperature for February. This month averages colder than January at the high altitude stations in northern counties but is warmer than January along the lake and in much of the southern districts. The normal for the state is 27°.

Mean temperature, February, 1912

Figure 9. Average temperatures for February, 1912. The unusually cold weather of January continued until the middle of February and made one of the longest low temperature periods in the history of the state. The ground was frozen to an unusual depth and there was much damage by the bursting of gas and water pipes. Between three and four hundred cases of frozen water pipes were reported to the Columbus Water Works Department.

Temperature departures, February, 1912

Scale of shades.

Below normal | Above normal

Figure 10. Departure of the mean temperature from the normal, February, 1912. It continued very cold during the first half of the month, making, with January, one of the most prolonged cold spells ever recorded in the state. At Columbus the mean temperature from January 1 to February 14 was 11.6° below the normal and was lower than for any other 45-day period in the history of the station. The second half was warmer, although there were two short periods when the temperature ranged considerably below the normal. The whole month averaged 4.4° below the normal.

Normal precipitation for February

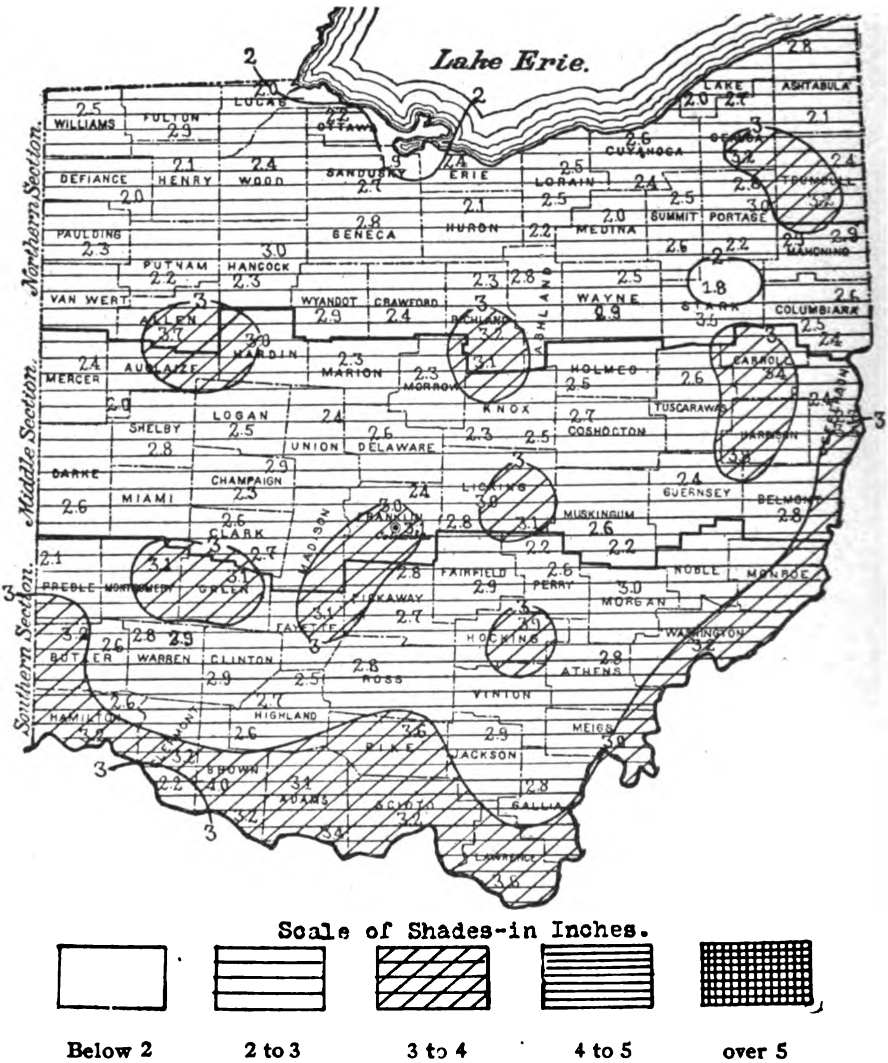


Figure 11. Average precipitation for February. The greatest fall is along the Ohio river and the least near the western part of Lake Erie, and in northern Stark county. The average fall for the state is 2.88 inches.

Precipitation, February, 1912

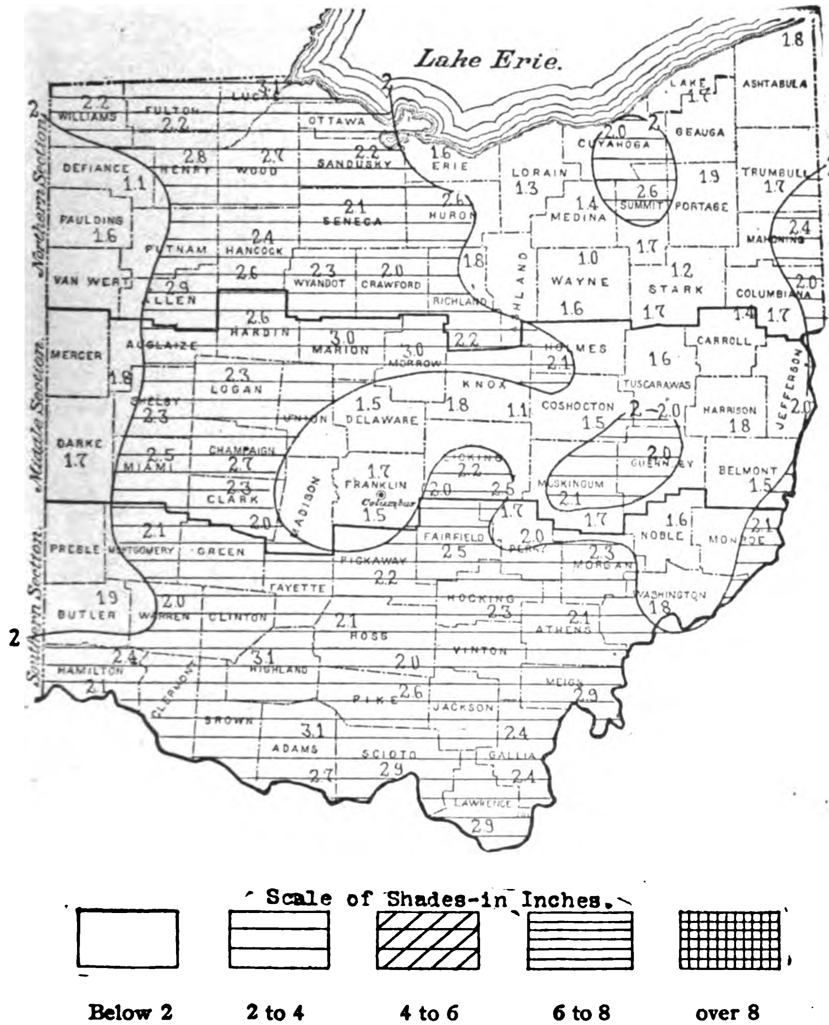


Figure 12. Total precipitation, February, 1912. The precipitation was well distributed and averaged 2.08 inches for the state. During the first half of the month it was generally light and mostly in the form of snow. The last part of the month was much more stormy than the first.

Precipitation departures, February, 1912

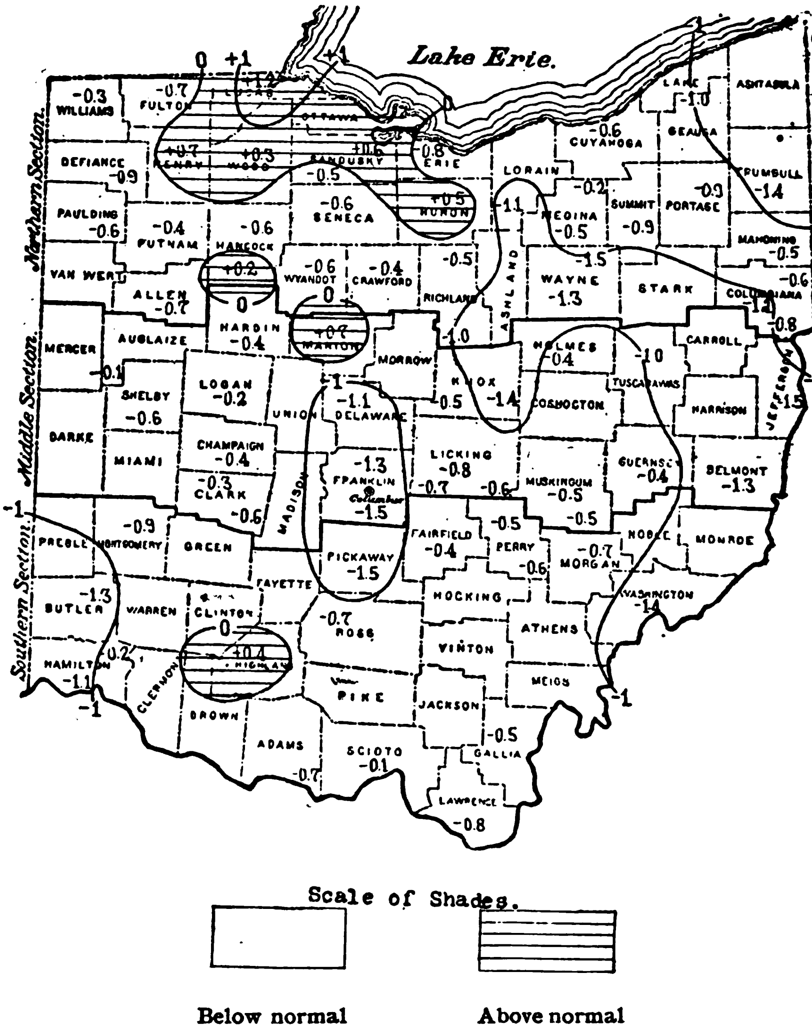
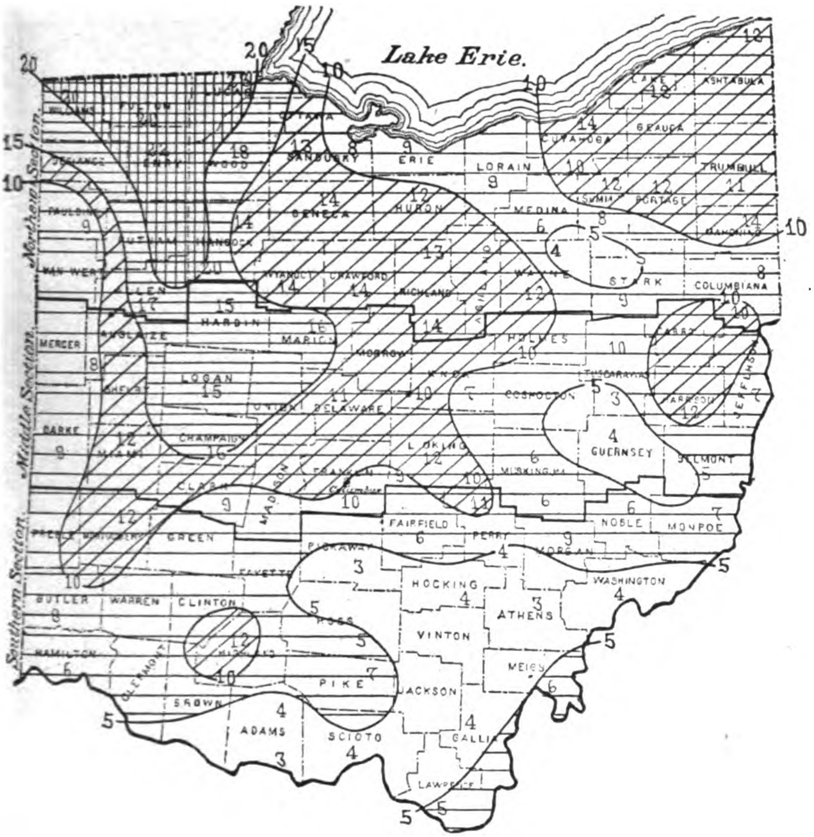


Figure 13. Departure of the precipitation from the normal, February, 1912. The precipitation averaged 0.61 inch less than the normal and was below the normal in nearly all districts. Some damage was caused by the breaking up of the ice in the large rivers and the forming of ice gorges.

Snowfall, February, 1912



Scale of Shades-in Inches.

Below 5	5 to 10	10 to 15	15 to 20	over 20

Figure 14. Total snowfall, February, 1912. The snowfall was generally above the normal, while in northwestern counties it was nearly double the usual amount. Much of this excessive amount in the northwest occurred in the storm of the 21st and 22nd, when damage was done by wind, sleet and snow. The ground was generally covered with snow during the first part of the month and during about half of the last part.

Mean temperature (normal) March

Figure 15. Normal temperature for March. The normal temperature for Ohio for March is 39°, or 12° higher than in February. The lowest for the month is near the Lake.

Mean temperature, March, 1912

Figure 16. Average temperatures for March, 1912. This was one of the coldest months of March on record. Following the cold weather of January and February, the three months gave the lowest mean temperature recorded since 1885. At Marietta, where there is a temperature record of 90 years, there have been only three periods of three months with lower mean temperatures—these were 1856, mean, 25.4°, 1885, mean, 28.4°; 1895, mean, 28.9°. This year it was 30.4°. The ground was frozen throughout the month and there were practically no building operations or farm work.

Temperature departures, March, 1912

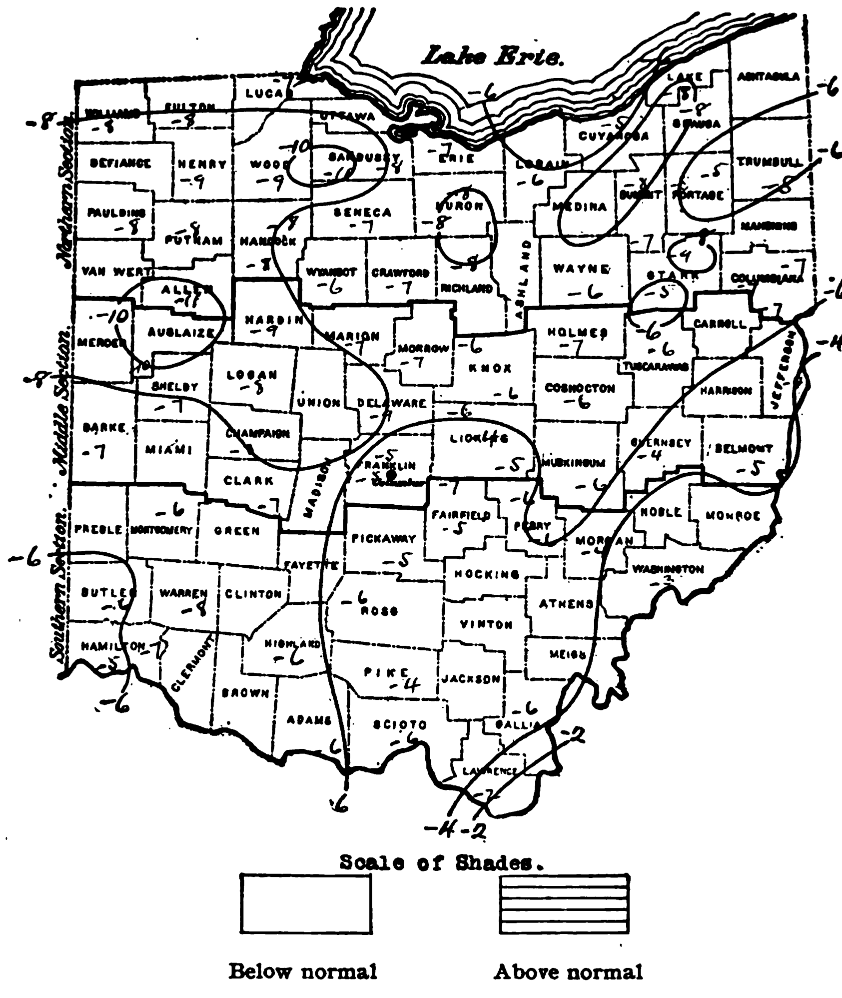


Fig. 17. Departure of the mean temperature from the normal, March, 1912. The temperature averaged 6.6° a day below the normal and was 11° below the normal in parts of Sandusky and Allen counties. The average temperature was below the normal on nearly every day during the month. Rivers and streams were covered with an unusual thickness of ice due to the extremely cold weather of the three months.

Normal precipitation for March

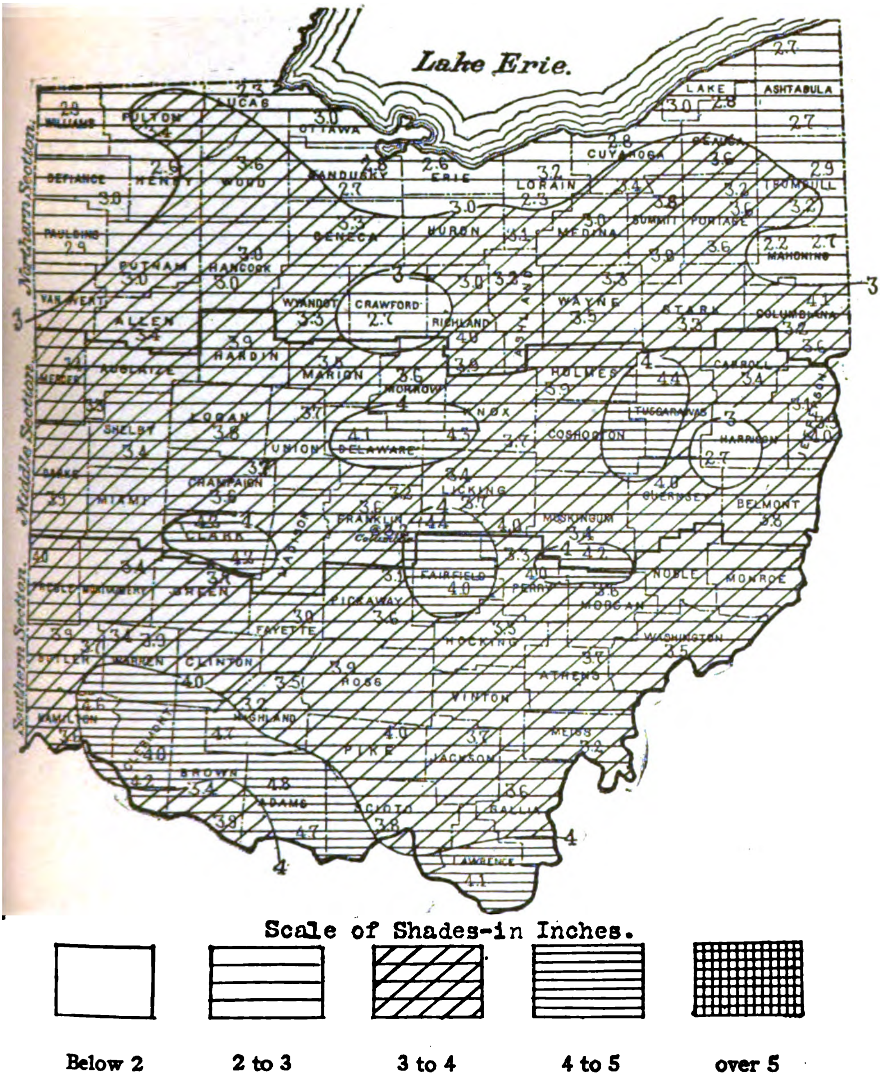


Figure 18. Average precipitation for March. The precipitation for March averages slightly higher than for either of the winter months, being 3.33 inches. The greatest fall is in central and southern counties and the least in the north.

Precipitation, March, 1912

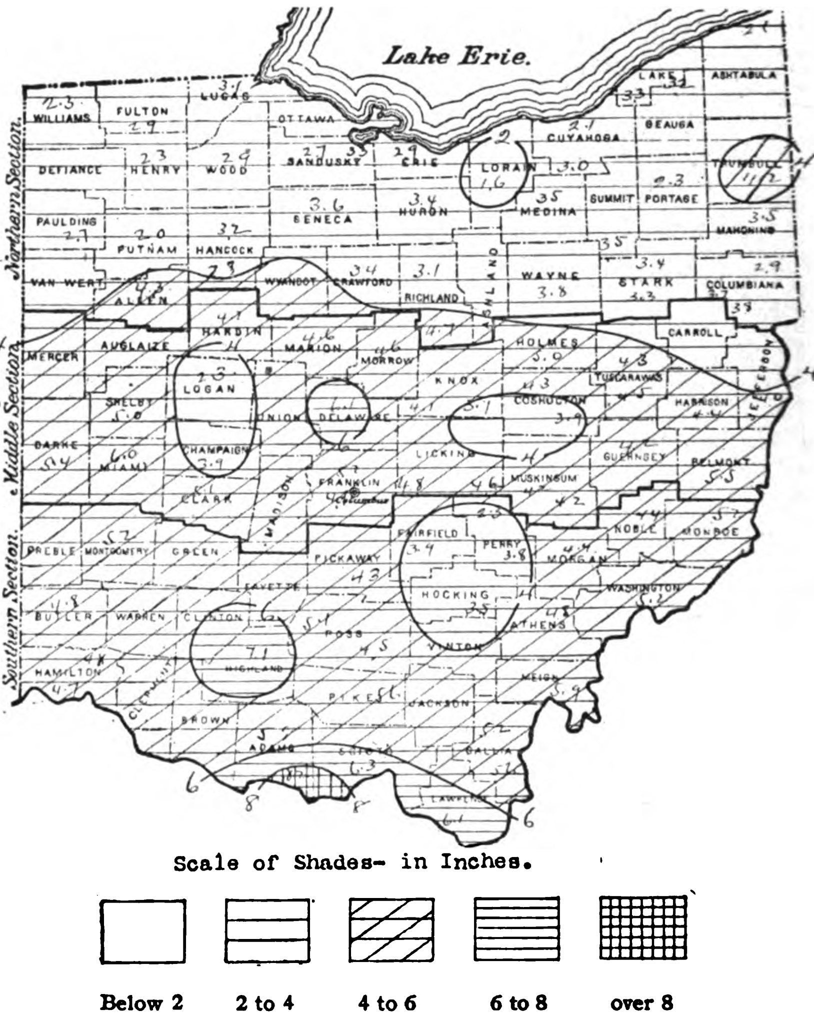


Figure 19. Total precipitation, March, 1912. The precipitation averaged 4.17 inches for the state. It was over 8 inches in southern Adams county and below 2 inches in Lorain county. It was frequent during the month. The weather was unfavorable for outdoor employment. Some damage was done by lightning on the 19th in Cincinnati. The ice in the rivers was broken up by rain and high temperature near the middle of the month, and during the last 15 days ice gorges were formed and high water occurred. The water was especially high in the Maumee and Sandusky rivers and considerable damage resulted.

Precipitation departures, March, 1912

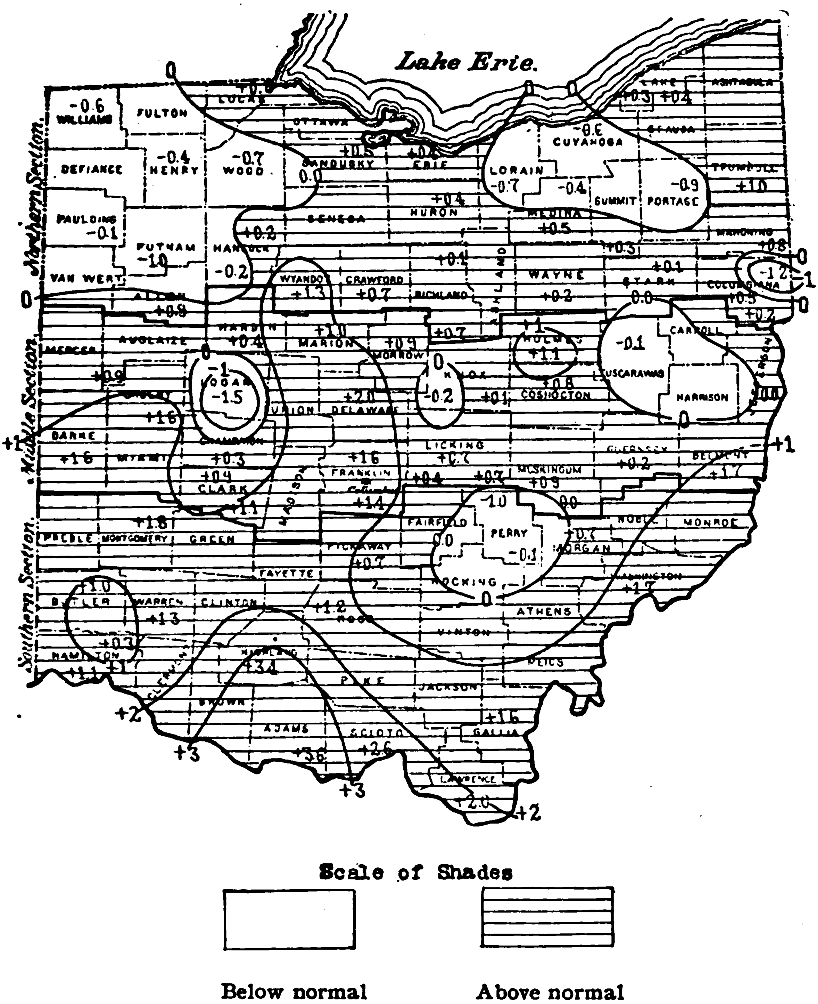


Figure 20. Departure of the precipitation from the normal, March, 1912. The precipitation was above the normal in most counties and averaged 0.59 inch above for the state. Precipitation was frequent.

Snowfall, March, 1912

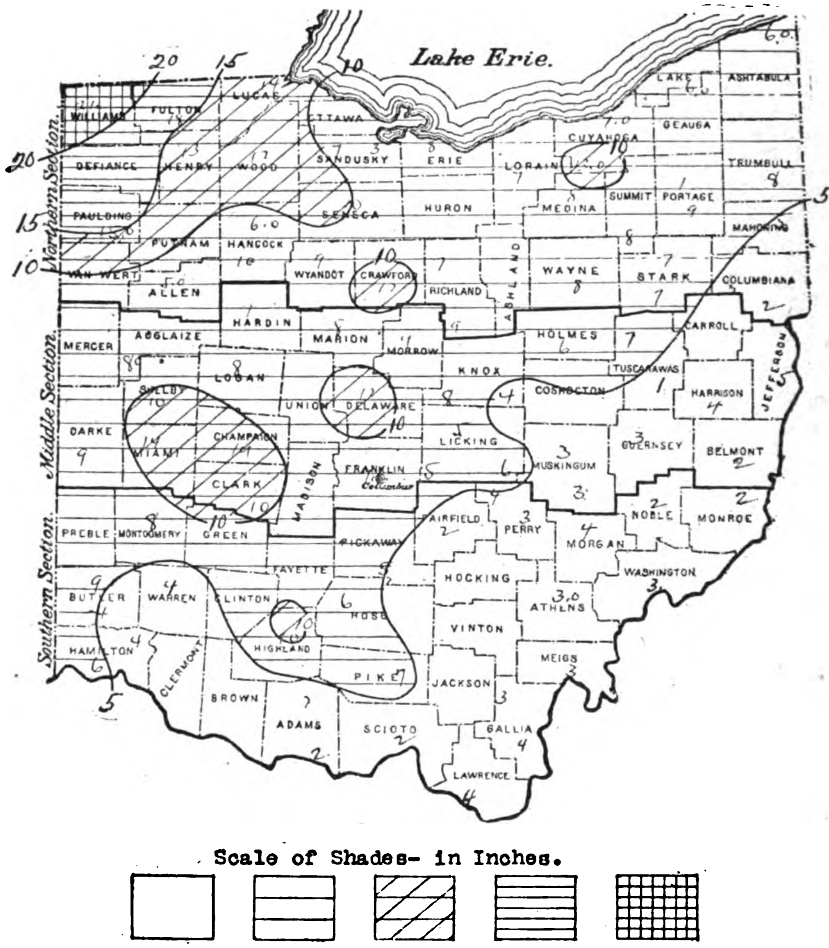


Figure 21. Total snowfall, March, 1912. The snowfall was above the normal for March, except in southeastern counties, where very little snow fell after the 11th. The fall was considerably greater than usual in northwestern districts. Traffic was hindered in northern counties by sleet and snow on the 20th and 21st and by snow on the 24th. In some central and most northwestern counties the ground was covered with snow most of the month.

Mean temperature (normal) April

Figure 22. Normal temperature for April. The rise in temperature during the spring in this state is very steady. The average for April is 49°. The coolest weather is in the extreme northeast.

Mean temperature, April, 1912

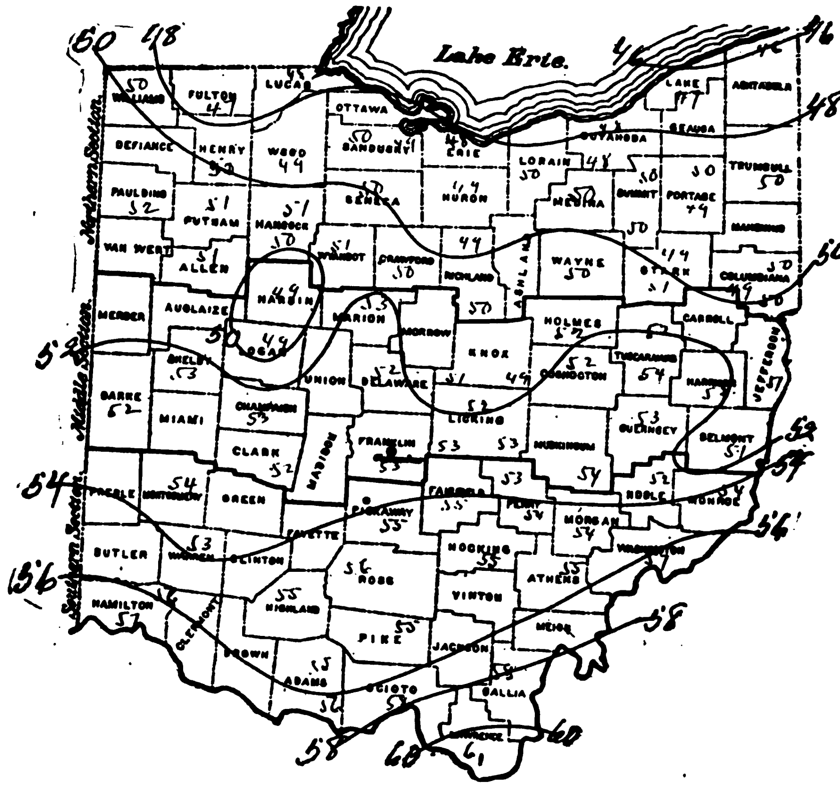


Figure 23. Average temperatures for April, 1912. The temperature was moderate with no extremely high or low readings. Freezing temperatures were general during the last 10 days. As the season advanced it was seen that the damage by the cold of the preceding months was very great.

Temperature departures, April, 1912

Scale of Shades.

Below normal Above normal

Figure 24. Departure of the mean temperature from the normal, April, 1912. The temperature was above the normal except in Hardin county and averaged 2.5° above for the state. The 2nd and 3rd were quite cold but a warm spell followed which lasted until the 16th. There were no extremely high or low temperatures.

Normal precipitation for April

Figure 25. Average precipitation for April. The distribution of the precipitation in April is quite different from that in March as will be seen by comparing this chart with No. 18. The average fall for the state is 3.03 inches.

Precipitation, April, 1912

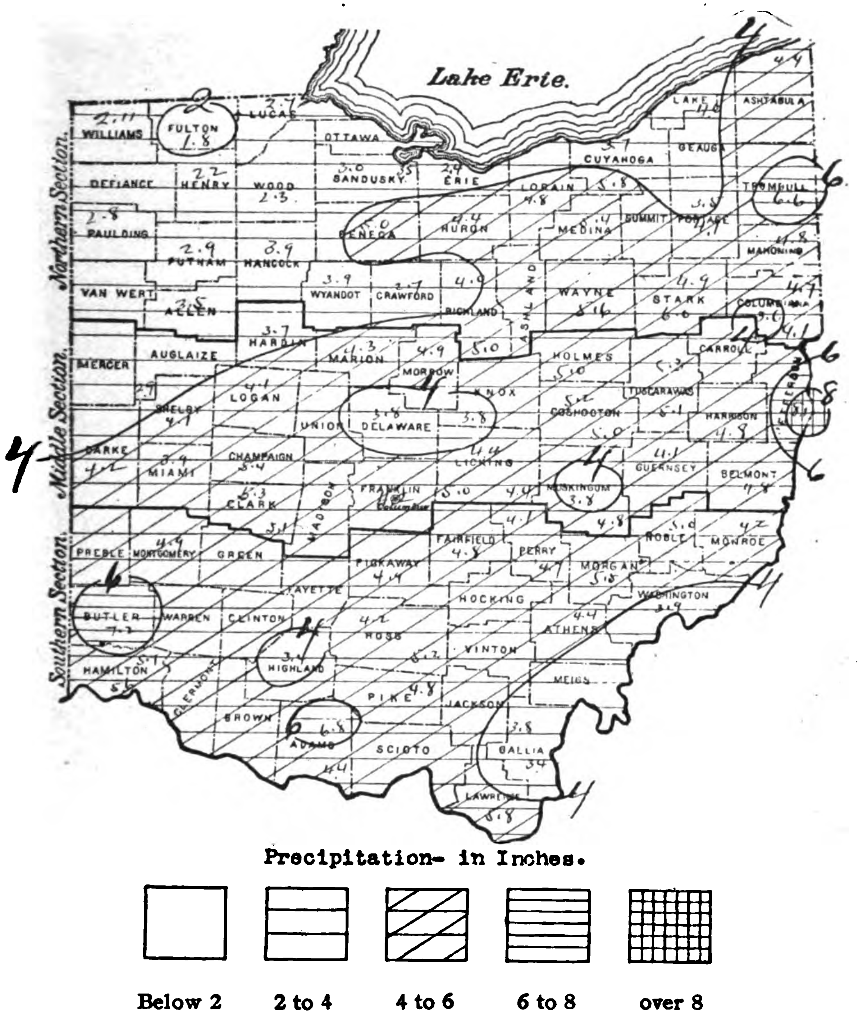


Figure 26. Total precipitation, April, 1912. The precipitation averaged 4.47 inches. The rains were well distributed throughout the month and in many central districts they occurred with such frequency that all outdoor work was greatly delayed. Thunderstorms occurred on several dates, the most damaging being on the 14th. This was accompanied by hail in many sections of the state and much damage resulted. The hailstones were unusually large.

Precipitation departures, April, 1912

Scale of Shades.

Below normal | Above normal

Figure 27. Departure of the precipitation from the normal, April, 1912. The average rainfall for April was 1.46 inch above the normal, although in some northwestern districts it was slightly less than the usual amount for this month. Only once in the past 30 years has the average for the state for this month been greater than this year.

Snowfall, April, 1912

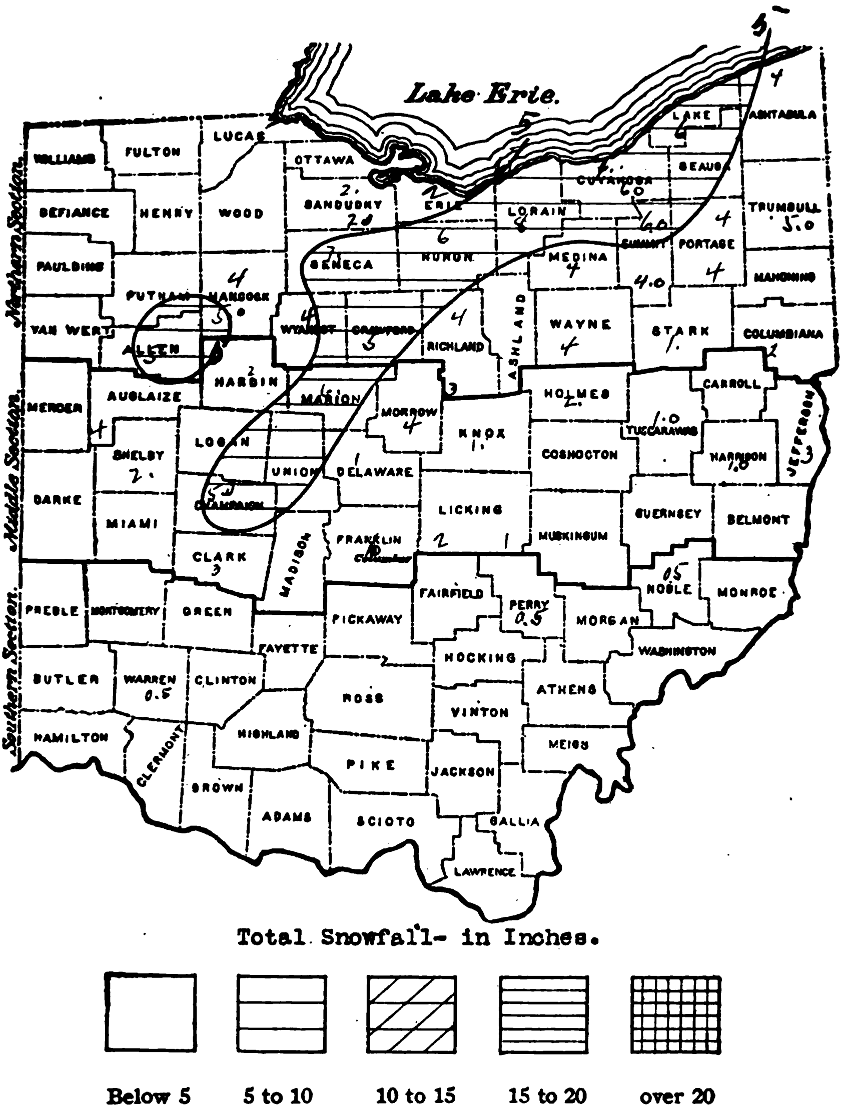


Figure 28. Total snowfall, April, 1912. Quite a heavy snowfall occurred in central and northeastern counties on April 2, amounting to over 5 inches in a number of places.

Mean temperature (normal) May

Figure 29. Normal temperature for May. The normal temperature for May is 61°. The coolest section of the state is in Lake county and the warmest near the Ohio river.

Mean temperature, May, 1912

Figure 30. Average temperatures for May, 1912. The warmest day was the 23rd, when several people were prostrated by the heat. The coldest day was the 13th when the temperature was below freezing at a number of points. The weather was cloudy, however, and comparatively little frost damage was reported.

Temperature departures, May, 1912

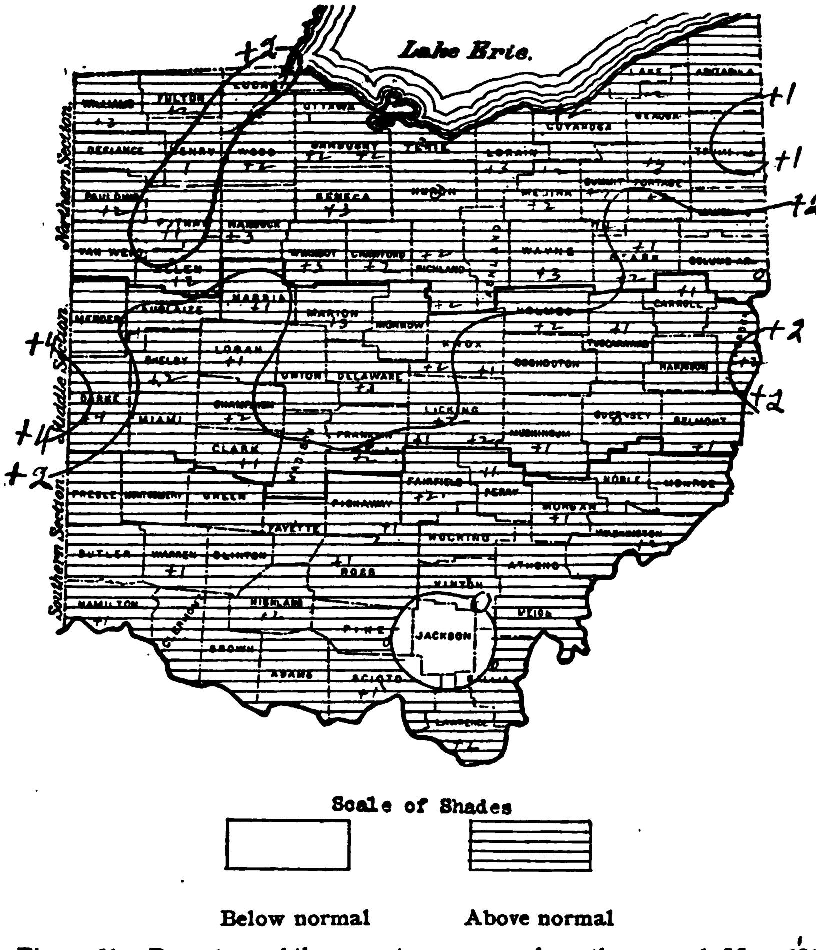


Figure 31. Departure of the mean temperature from the normal, May, 1912. The temperature averaged 1.7° a day above the normal during May. The daily temperatures were considerably above the normal during most of the first week and again on the 20th-24th and 27th-28th. The 23rd was the warmest day of the month at most stations and the 13th was the coldest.

Normal precipitation for May

Figure 32. Average precipitation for May. The precipitation increases steadily through May into June, the average for May for the state being 3.77 inches. The distribution over the state is very uniform, as is shown by the above chart.

Precipitation, May, 1912

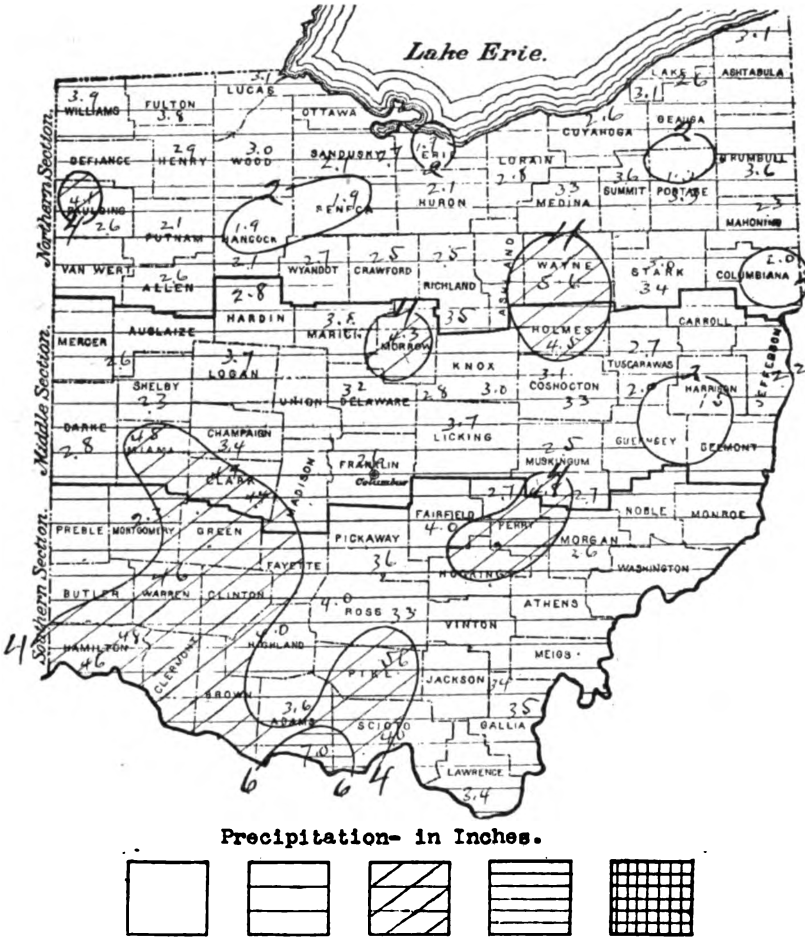
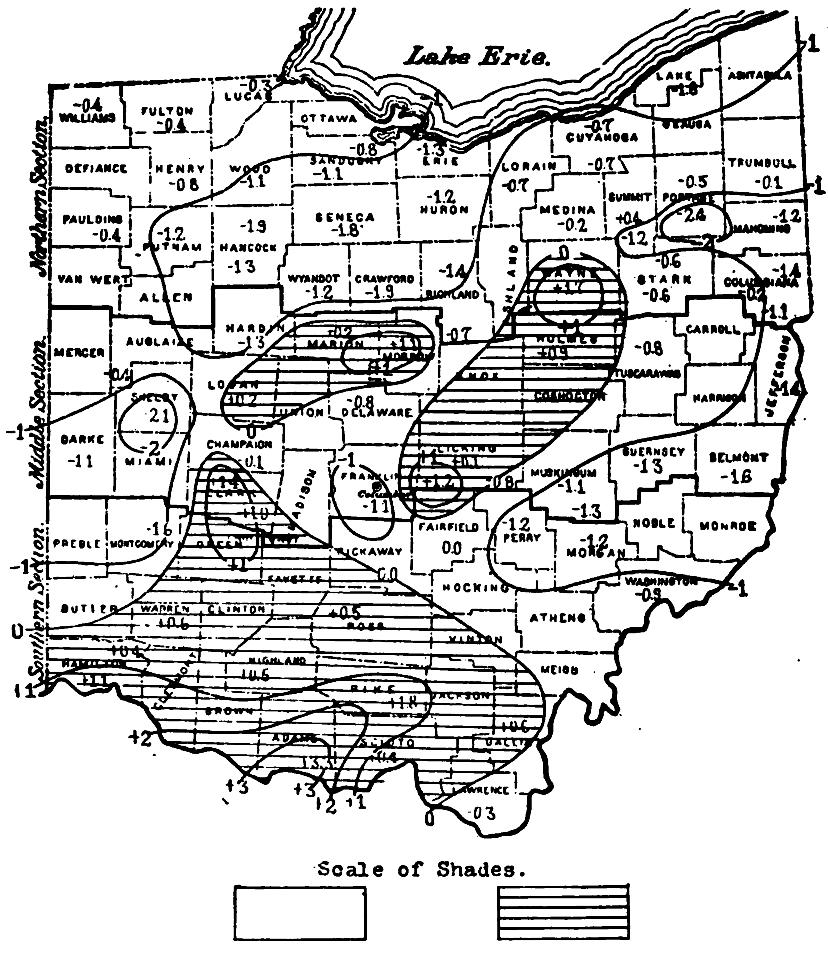


Figure 33. Total precipitation, May, 1912. The average precipitation was 3.12 inches and was rather irregularly distributed. The fall was 7 inches in southern Adams county, but less than 2 inches in a number of northern and eastern districts. There was much rainy weather from the 11th to 17th which delayed farm work seriously, although this was followed by a week of very favorable conditions. The thunderstorms that occurred were not generally severe.

Precipitation departures, May, 1912



Scale of Shades.

Below normal Above normal

Figure 34. Departure of the precipitation from the normal, May, 1912. The average precipitation for the state was 0.51 inch less than the normal, although it was greater than the normal in most southern and some central districts.

Snowfall, May, 1912

Figure 35. Total snowfall, May, 1912. Snow fell in central and northern districts on the 13th but in most places it melted as fast as it fell.

Mean temperature (normal) June

Figure 36. Normal temperature for June. The normal for June is 69°.

Mean temperature, June, 1912

Figure 37. Average temperature for June, 1912. The night temperatures were unusually low during the first half of June and the germination and growth of vegetation was retarded. Corn suffered the greatest damage in this respect. Freezing temperatures were general in the valleys in the eastern portion of the state on the 7th or 8th, and frost was general except in a few western counties. At Green Hill, Columbiana county, a temperature of 28° was recorded on the 8th. This is the lowest record in June since the establishment of the Meteorological Service in 1883.

Temperature departures, June, 1912

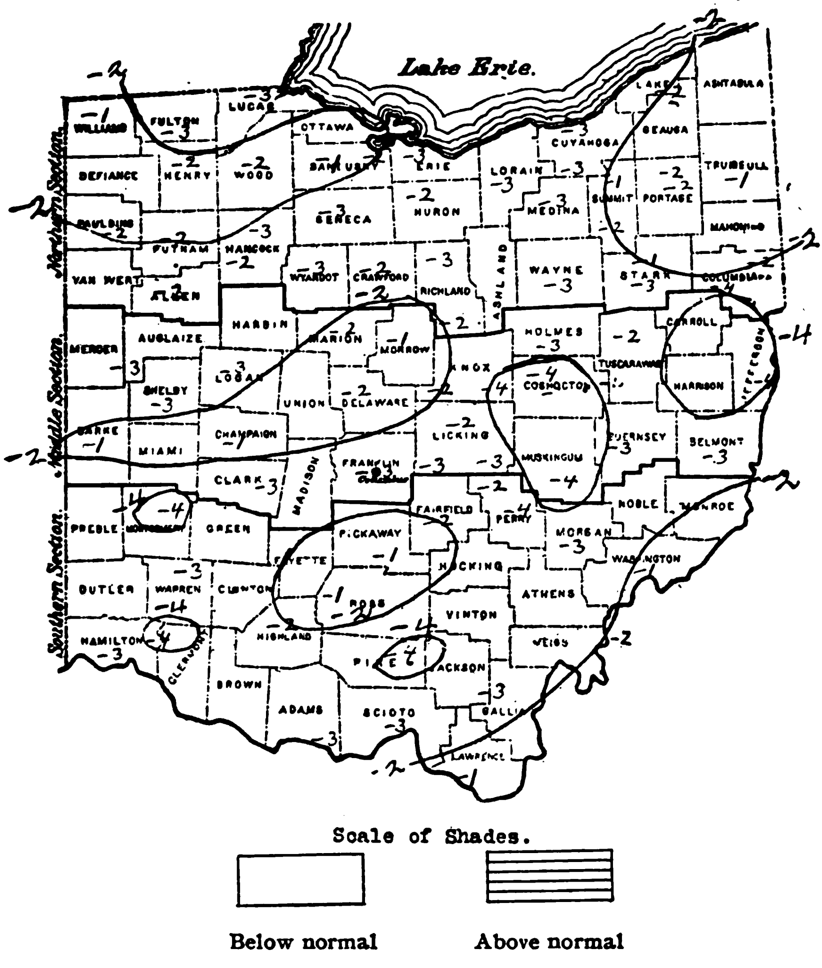


Figure 38. Departure of the mean temperature from the normal, June, 1912. The temperature averaged unusually low during the first half of the month, although it was more favorable during the last half. The daily temperature for the state averaged 2.6° below the normal, and was 4° or more below in some districts.

Normal precipitation for June

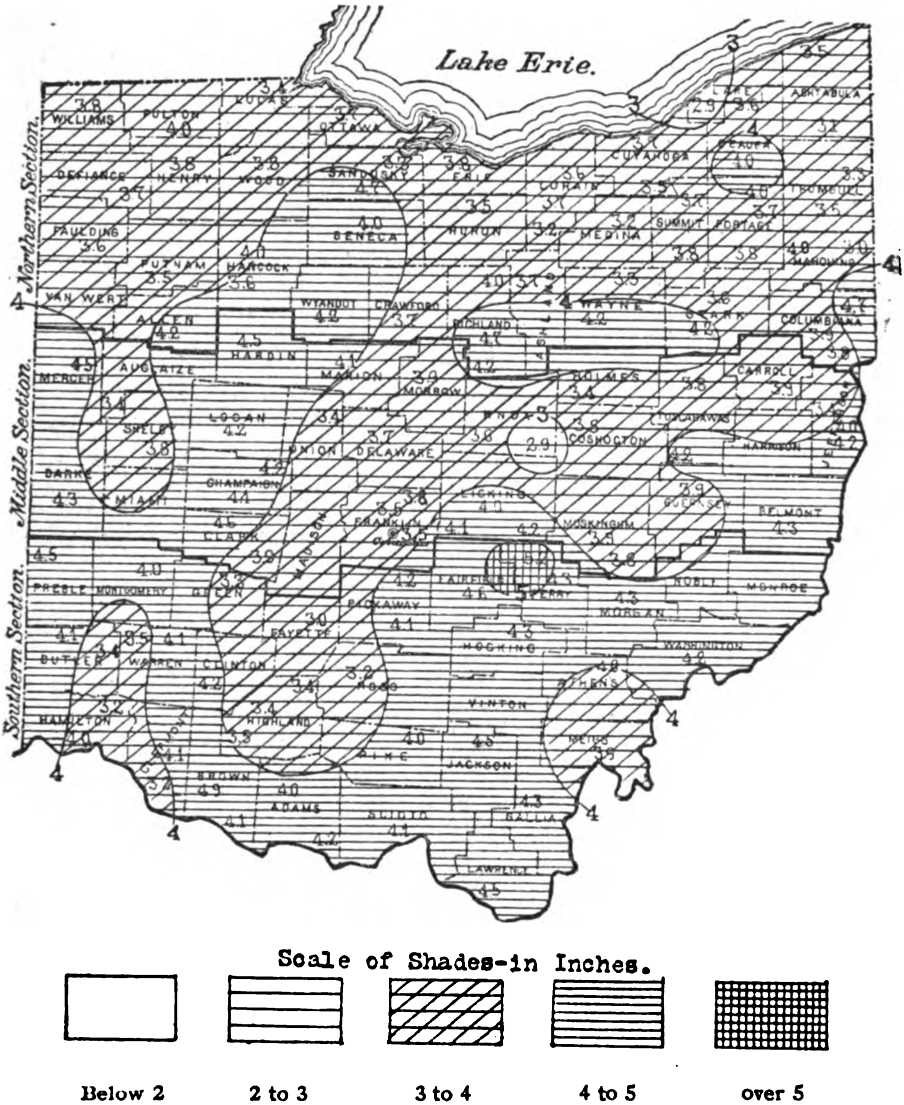


Figure 39. Average precipitation for June. This is normally the wettest month of the year in Ohio. The average rainfall for the state is 4.13 inches and it is well distributed over the state.

Precipitation, June, 1912

Scale of Shades-in Inches.

Below 2 | 2 to 4 | 4 to 6 | 6 to 8 | over 8

Figure 40. Total precipitation, June, 1912. The average rainfall for the state was 3.17 inches, but it was very unevenly distributed. The number of rainy days was considerably below the average. Most of the rainfall occurred in scattered thunderstorms. A number of unusually severe storms occurred on Sunday, June 16th, and much damage resulted from both wind and lightning. The wind injured buildings, orchards, timberlots, and telephone and telegraph lines from Cincinnati northeasterly across the central portion of the state.

Precipitation departures, June, 1912

Scale of Shades.

Below normal Above normal

Figure 41. Departure of the precipitation from the normal, June, 1912. The precipitation was unevenly distributed and in some districts was considerably above the normal, but for the state as a whole it averaged 0.77 inch less than the usual amount. Very little rain fell during the first 11 days of the month.

Mean temperature (normal) July

Figure 42. Normal temperature for July. The normal for July is 74°. This is the warmest month of the year, although some seasons the mean temperature for June or August or both may be higher than in July. The lowest mean temperature is in eastern Portage county and the highest at Cincinnati.

Mean temperature, July, 1912

Figure 43. Average temperature for July, 1912. The month was characterized by unusual evenness in temperature with no unusually low or high temperatures. The highest mean was 77° in the Ohio valley and the lowest 70° in northeastern counties.

Temperature departures, July, 1912

Scale of Shades:

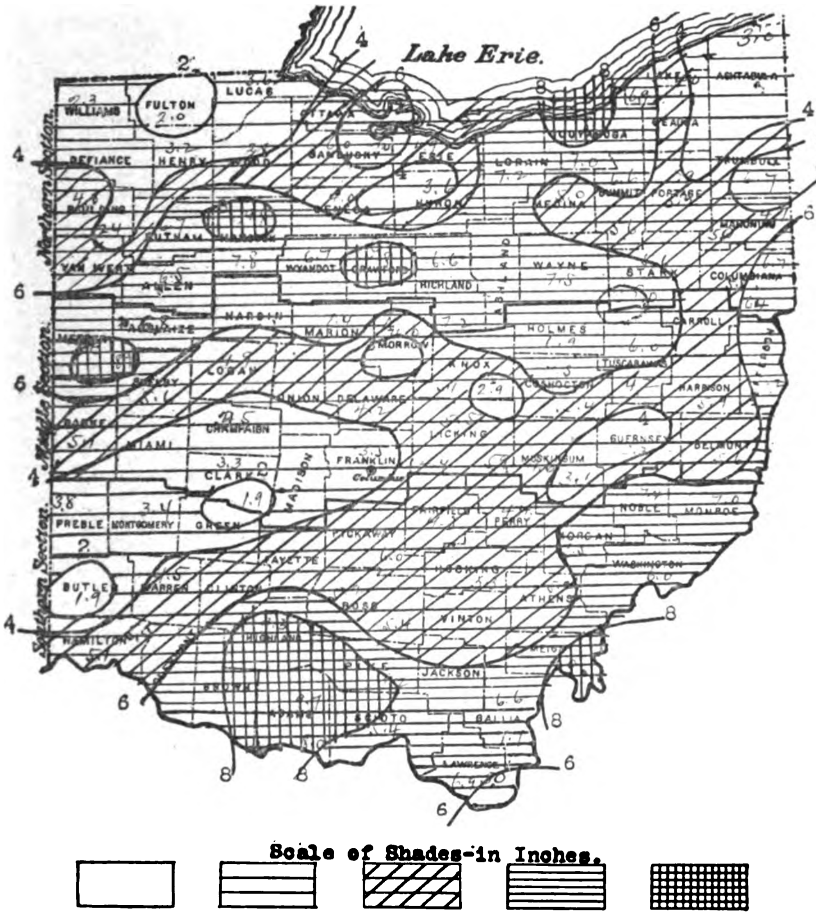
Below normal Above normal

Figure 44. Departure of the mean temperature from the normal, July, 1912. For the state as a whole the temperature averaged almost exactly normal. It was generally slightly warmer than the normal during the first half and slightly cooler during the last half of the month, although the ranges were not great.

Normal precipitation for July.

Figure 45. Average precipitation for July. July averages nearly as wet as June, the rainfall for the state being 4.04 inches. The eastern half of the state averages slightly more rainfall than the western half.

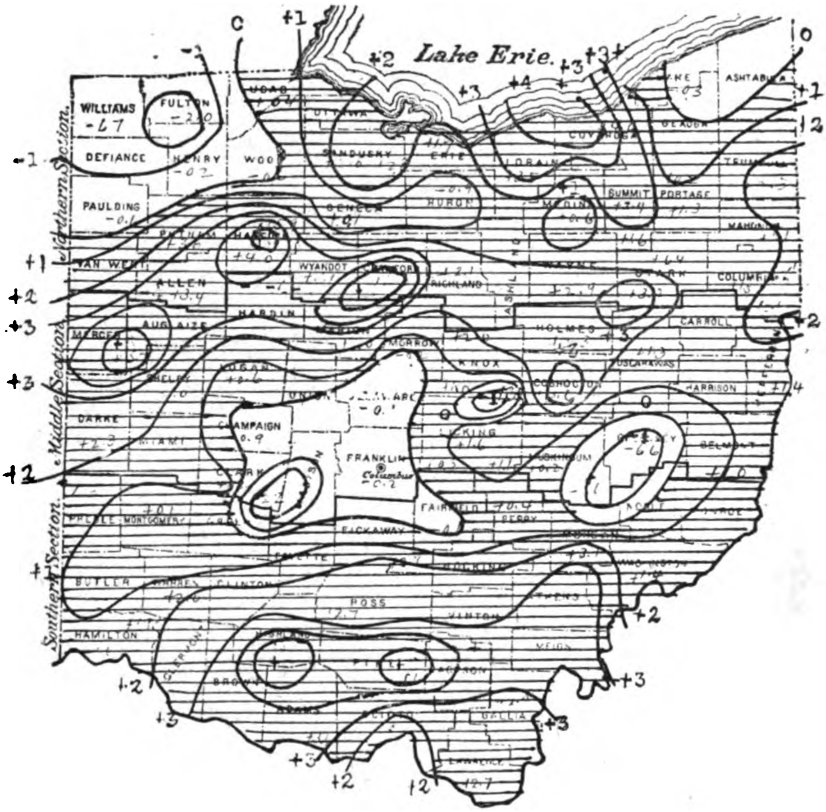
Precipitation, July, 1912



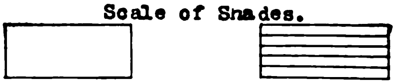
Below 2 | 2 to 4 | 4 to 6 | 6 to 8 | over 8

Figure 46. Total precipitation, July, 1912. The average rainfall for July for the state was 5.70 inches. It was over 9 inches in central Adams county but less than 2 inches in Butler and southern Adams counties. The rains were frequent and heavy and at a number of points more rain fell than during any other July on record. Thunderstorms were frequent and damaging, harvesting was hindered by the heavy rains and, in eastern and southern Ohio, much damage was done to roads, bridges and crops.

Precipitation departures, July, 1912



Scale of Shades.



Below normal Above normal

Figure 47. Departure of the precipitation from the normal, July, 1912. The average rainfall for Ohio was 1.65 inch above the normal in July, although in some central and northern counties it was considerably less than the usual amount. The rainfall is usually poorly distributed during summer thunderstorms, but it was unusually so during this month.

Mean temperature (normal) August

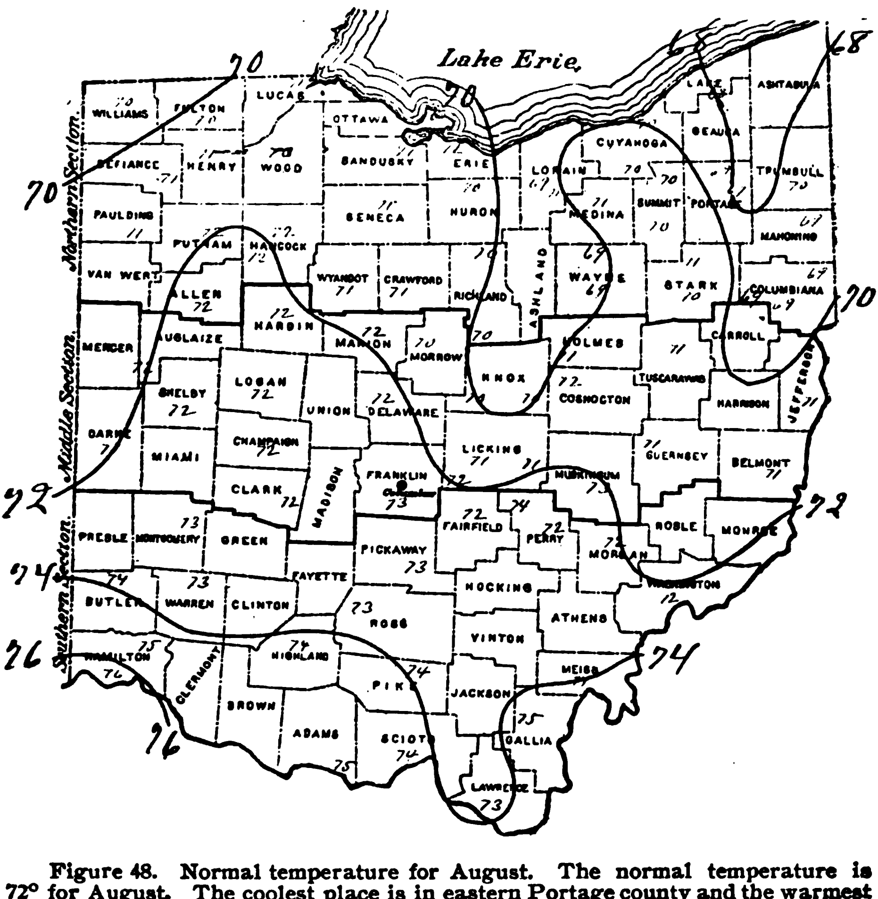


Figure 48. Normal temperature for August. The normal temperature is 72° for August. The coolest place is in eastern Portage county and the warmest at Cincinnati, as in July.

Mean temperature, August, 1912

Figure 49. Average temperature for August, 1912. The mean temperature for the state was 69.2°. The highest mean was 73.8° at Cincinnati and Ironton and the lowest 64.8° at Green Hill, Columbiana county. The highest temperature reported was 95° at two southern stations on the 18th and the lowest 40° at three eastern stations on the 4th. This was one of the coldest Augusts on record in this state.

Temperature departures, August, 1912

Scale of shades.

Below normal

Above normal

Figure 50. Temperature departures from the normal for August, 1912. The mean temperature for the month was 2.3° below the normal. The first week was unseasonably cool and the second was generally slightly below the normal. The 18th and 31st were the two warmest days.

Normal precipitation for August

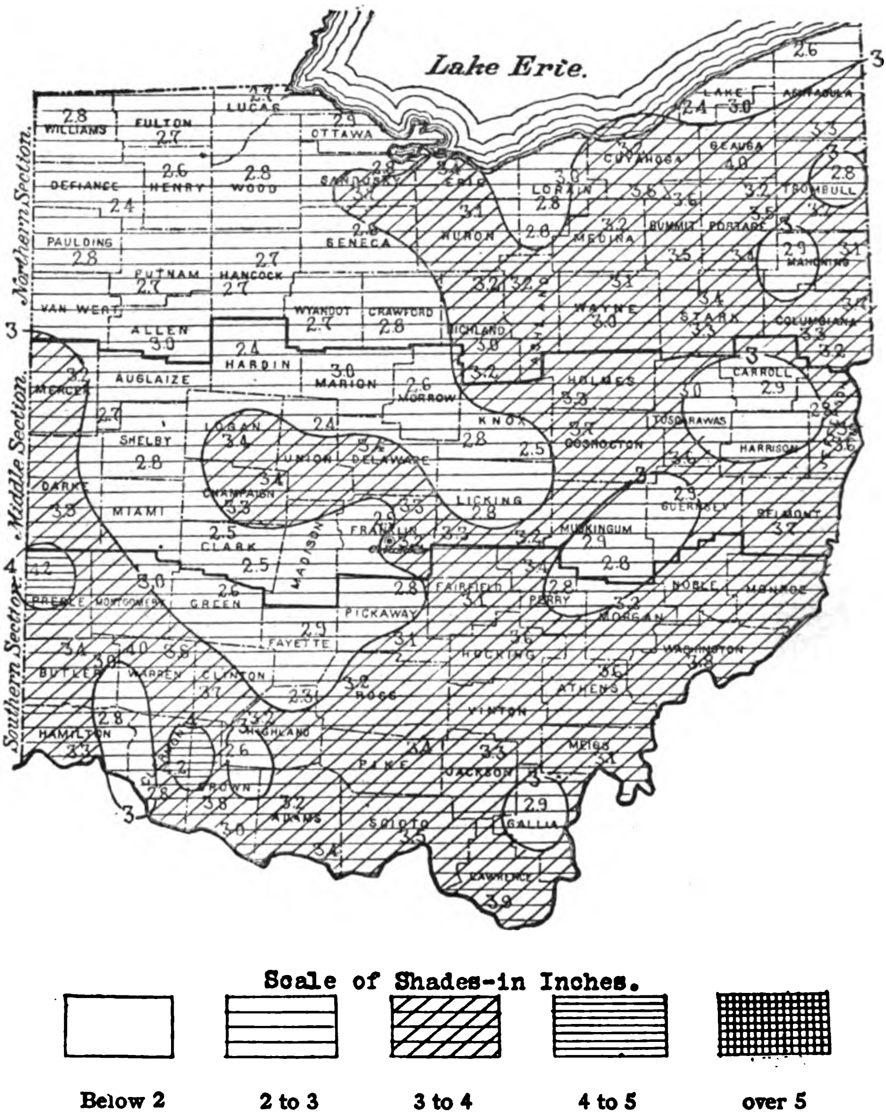


Figure 51. Average precipitation for August. Northwestern Ohio averages less rainfall in August than the other districts of the state. The mean is 3.27 inches.

Precipitation, August, 1912

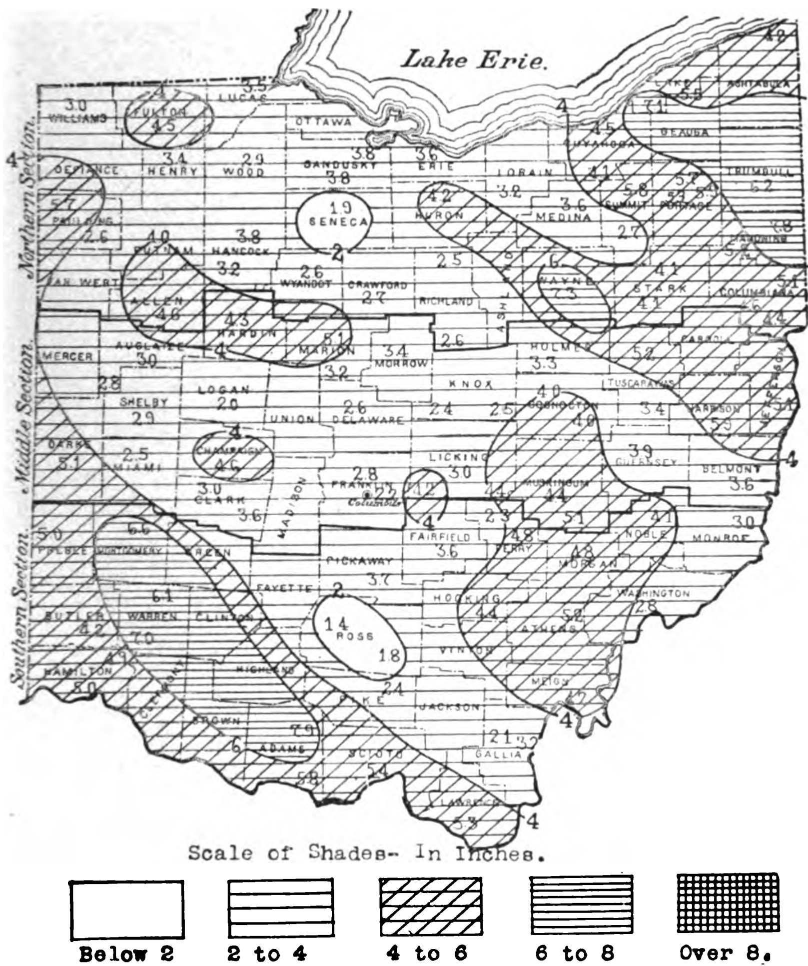


Figure 52. Precipitation during August, 1912. The average rainfall for the state was 4.08 inches. The rains were very frequent after the first week and harvesting and fall plowing were badly delayed. Considerable damage was done to crops, roads, and bridges by the heavy rains.

Precipitation departures, August, 1912

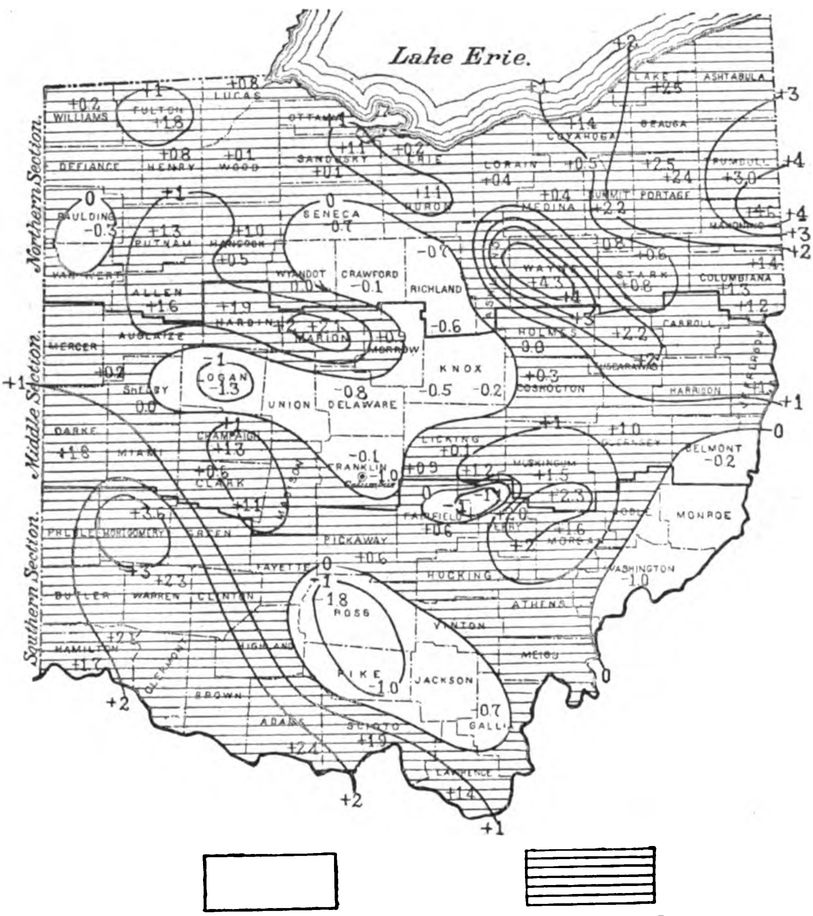


Figure 53. Precipitation departure from the normal for August, 1912. The average amount of rainfall for the state was nearly an inch above the normal. Locally the monthly totals were above normal at four-fifths of the stations. The greatest monthly amount reported was 7.90 inches at Peebles, Adams county, and the least 1.44 inch at Frankfort, Ross county.

Mean temperature (normal) September

Figure 54. Normal temperature for September. This month averages somewhat cooler than either June, July or August. The normal temperature is 66°.

Mean temperature, September, 1912

Figure 55. Average temperature for September, 1912. The highest mean temperature was in Meigs county and the lowest in Portage and Columbiana counties. The average for the state was 67.4°. The highest recorded was 99° in Morrow county on the 5th and the lowest 29° in Hardin county on the 27th. The first 11 days of the month were unusually warm and several heat prostrations were reported. Frosts were general during the last four days of the month.

Temperature departures, September, 1912

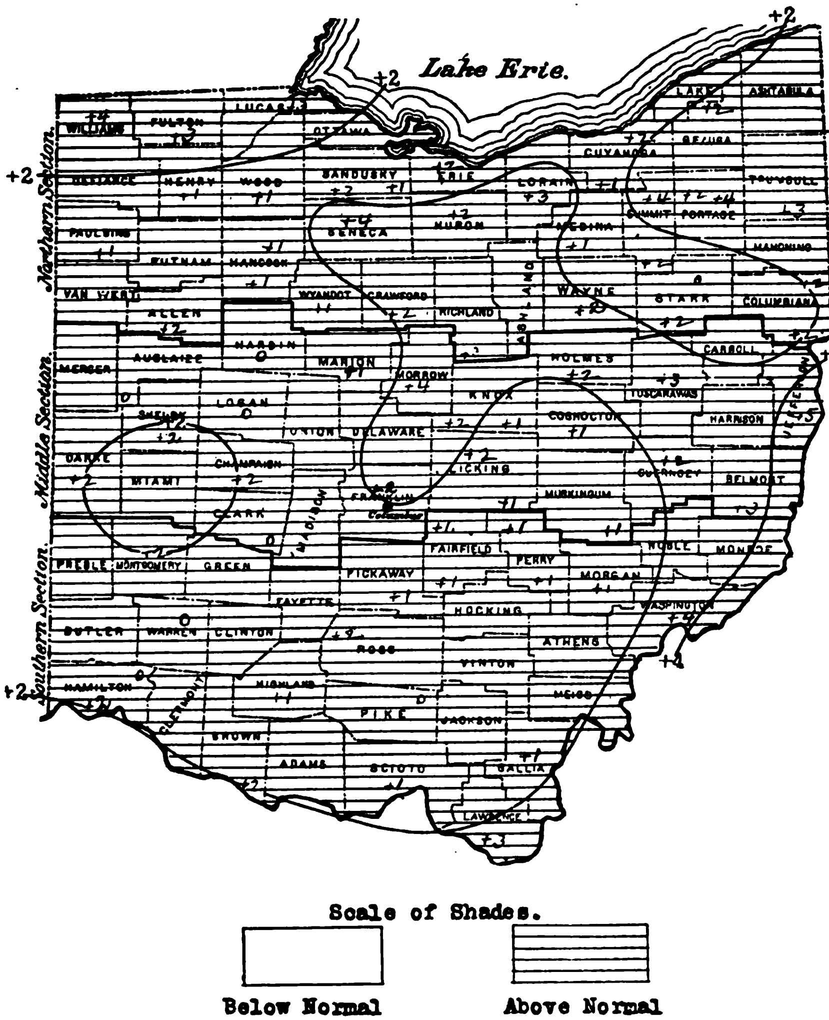


Figure 56. Departure of the mean monthly temperatures from the normal for September, 1912. The month was warmer than usual in all sections of the state, the average being 1.7° above the normal. The daily temperatures at Columbus from the 1st to 11th averaged 11° above the normal. From the 12th to the 25th the temperatures were near the normal, but decidedly cooler weather prevailed until from the 26th to 30th. Most observers report that damage to growing crops by the frosts near the close of the month was not extensive.

Normal precipitation for September

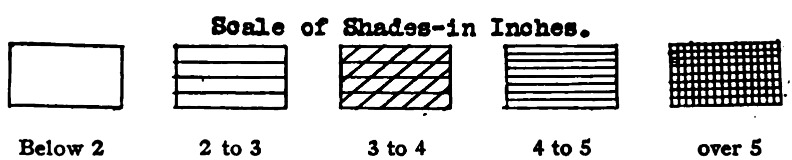


Figure 57. Average precipitation for September. The average rainfall for the state is 2.99 inches, the fall being greatest in northeastern counties.

Precipitation, September, 1912

Scale of Shades-in Inches.

Below 2	2 to 4	4 to 6	6 to 8	Over 8

Figure 58. Precipitation during September, 1912. The heaviest rainfall was in the northeast and the least in the southeast. The average rainfall for the state was 3.11 inches. Excessive rains on the 1st and 2nd caused a great deal of damage in Carroll, Columbiana, Jefferson and southern Stark counties Much damage was done in Wayne county on the 6th by heavy rain and lightning.

Precipitation departures, September, 1912

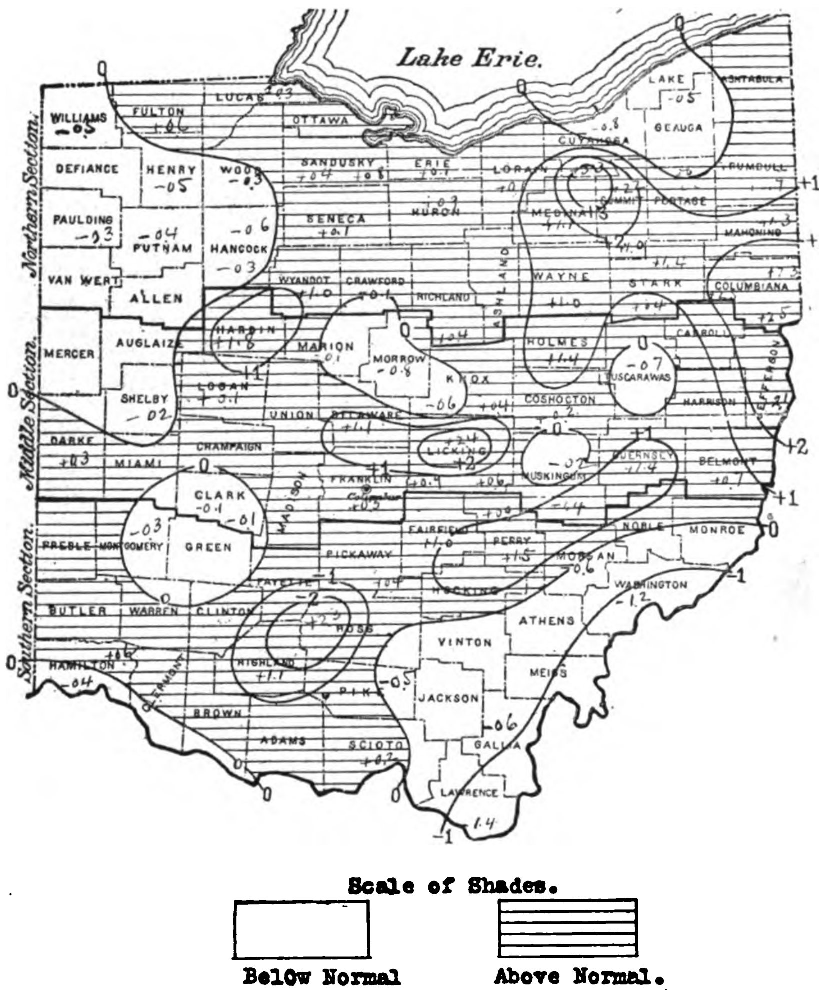


Figure 59. Departure of the rainfall for September, 1912, from the normal. The central and east-central portions of the state received the greatest rainfall. The amount for the state as a whole averaged 0.5 inch above the normal. The first half of the month was especially favorable for farm work and the maturing of corn and other crops.

Mean temperature (normal) October

Figure 60. Normal temperature for October. The fall of temperature in the autumn is rather more rapid than the rise in the spring. The normal temperature for October is 53°, or 13° lower than in September. The influence of the warm water of the Lake begins to be marked and the coolest places are at some distance from the Lake shore.

Mean temperature, October, 1912

Figure 61. Average temperature for October, 1912. The average temperature for the state was 54.8°. The highest local monthly mean was 60.8° in Green county and the lowest 51.0° in Columbiana county. The highest temperature reported was 93° in Belmont county on the 11th and the lowest was 23° in Adams county on the 26th and 27th, and in Perry county on the 27th. Light to heavy frosts were quite general on the first three days and in a few eastern counties the temperature fell to the freezing point. Killing frost occurred in some eastern counties on the 14th and on the 16th killing frost and freezing temperatures were general.

Temperature departures, October, 1912

Scale of Shades.

Below normal — Above normal

Figure 62. Temperature departures from the normal for October, 1912. The mean temperature for the state was 1.8° above the normal. The daily temperatures were generally above normal from the 4th to the 12th, 18th to 22nd, and 28th to 31st, inclusive, and below normal on most of the remaining dates. The warmest period of the month was from the 9th to the 11th. The many mild, pleasant days were especially favorable for late crops and outdoor work.

Normal precipitation for October

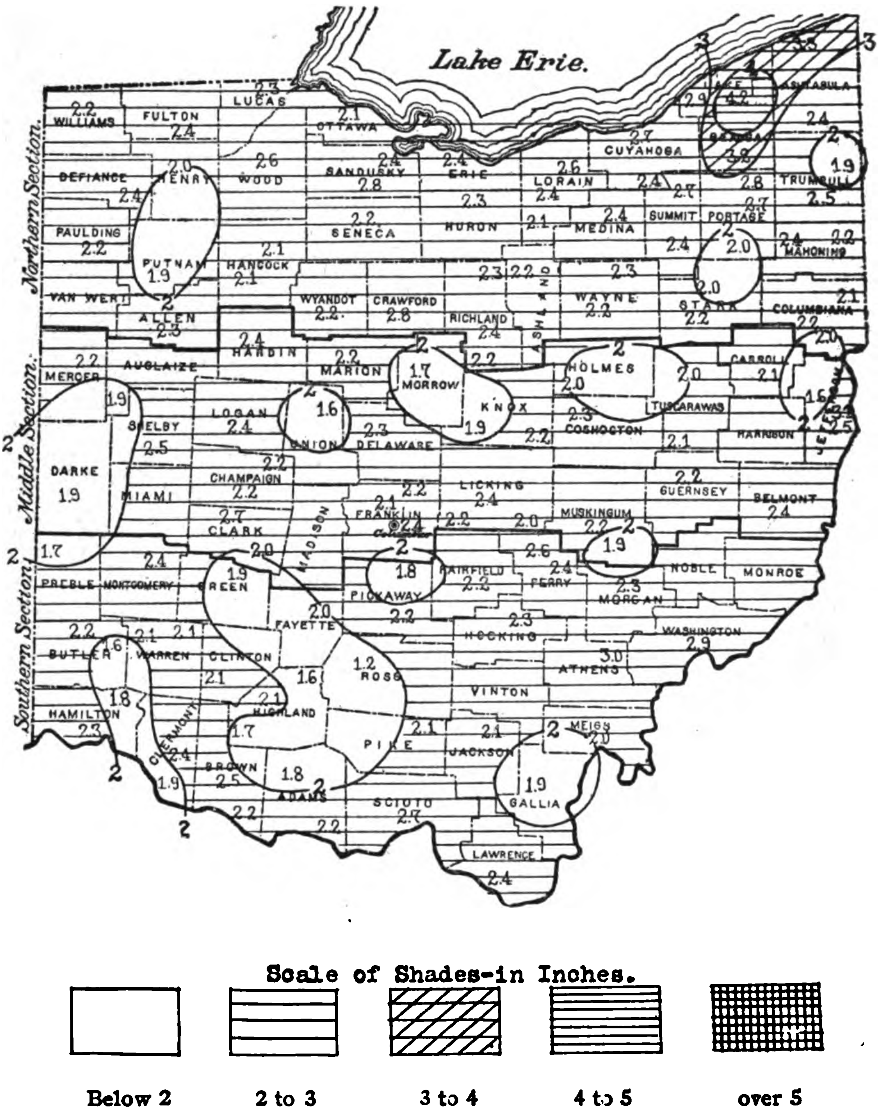


Figure 63. Average precipitation for October. October is the driest month of the year in Ohio, the average rainfall being 2.52 inches.

Precipitation, October, 1912

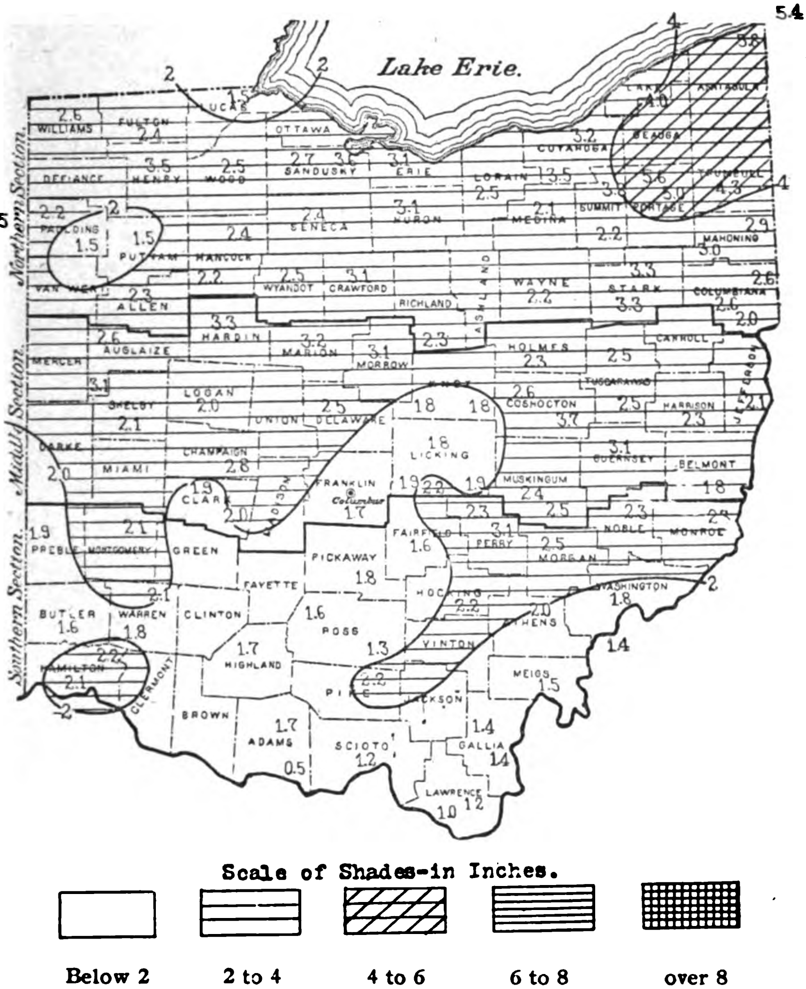


Figure 64. Precipitation during October, 1912. The average amount of precipitation for the state was 2.44 inches. In general it was heavier in the northeastern counties than elsewhere. The rainfall was light and scattered during the first 17 days, except in some of the northern counties. Then followed two 2-day periods of general rain on the 18th, 19th, 22nd and 23rd, and scattered showers occurred again on the last two days.

Precipitation departures, October, 1912

Scale of Shades.

Below normal — Above normal

Figure 65. Precipitation departure from the normal for October, 1912. Although there were but few rainy days, the total rainfall for the month averaged 0.18 inch above the normal. There was but little wet weather to interfere with work and yet in most places there was sufficient moisture to germinate seed and keep the fall pastures green.

Mean temperature (normal) November

Figure 66. Normal temperature for November. The normal temperature for November is 41°, or 12° lower than for October. The lowest mean temperature is in Fulton county and the highest at Cincinnati and Portsmouth.

Mean temperature, November, 1912

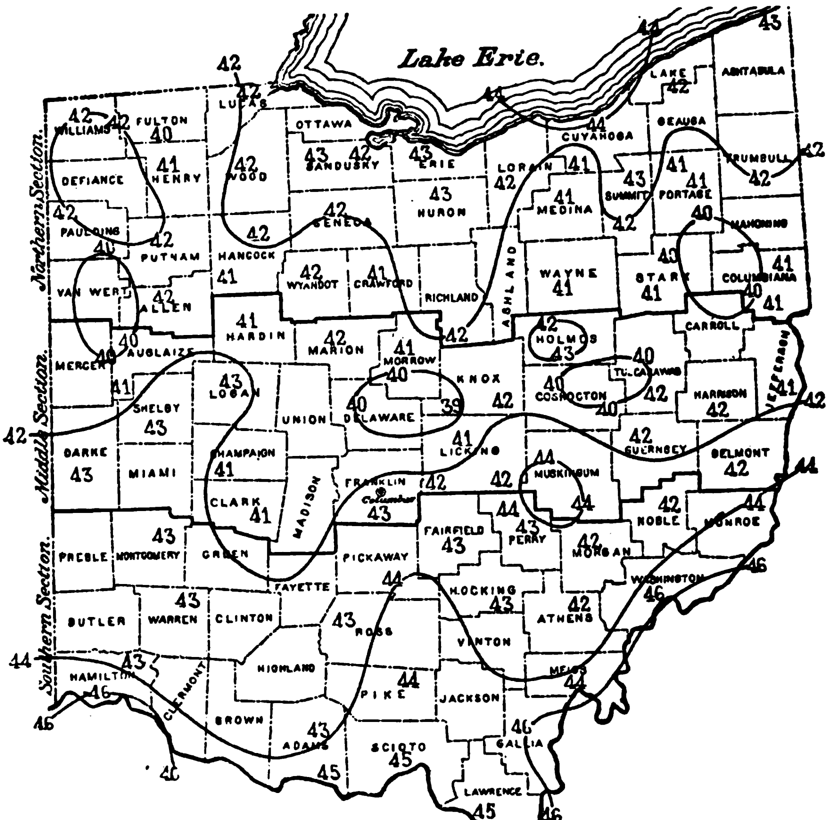


Figure 67. Average temperature for November, 1912. The lowest mean temperatures were in the central portion of the state instead of the northern, because of the effect of the comparatively warm waters of the Lake. The temperatures were generally below 20° on the 28th.

Temperature departures, November, 1912

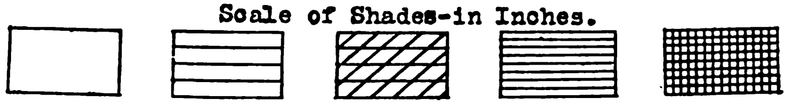
Scale of Shades.

Below normal Above normal

Figure 68. Departure of the average temperatures from the normal. The temperature averaged more than 2 degrees a day above the normal in most northern districts, and was slightly below the normal in a few central counties.

Normal precipitation for November

Scale of Shades-in Inches.



Below 2 | 2 to 3 | 3 to 4 | 4 to 5 | over 5

Figure 69. Average precipitation for November. The average for the state or this month is 2.99 inches.

Precipitation, November, 1912

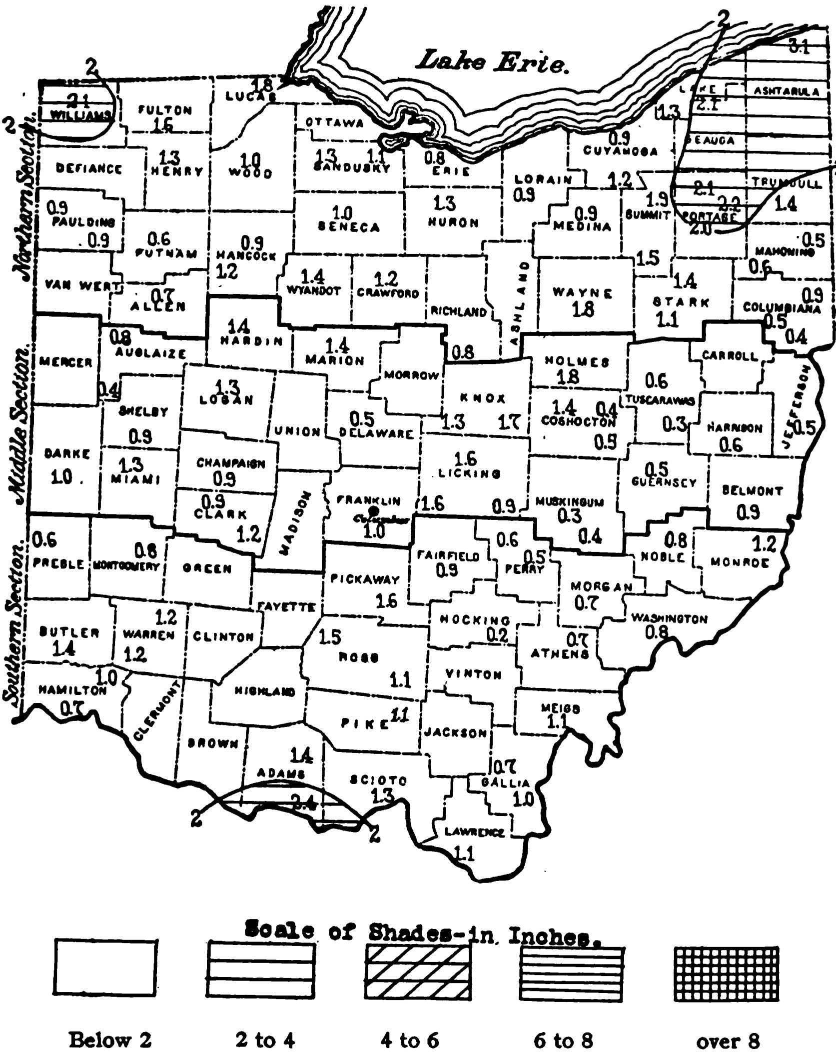


Figure 70. Total precipitation, November, 1912. The precipitation was heaviest in northeastern counties, but was very light in all sections. Most of the precipitation came before the 15th, so that the last half of the month was especially dry.

Precipitation departures, November, 1912

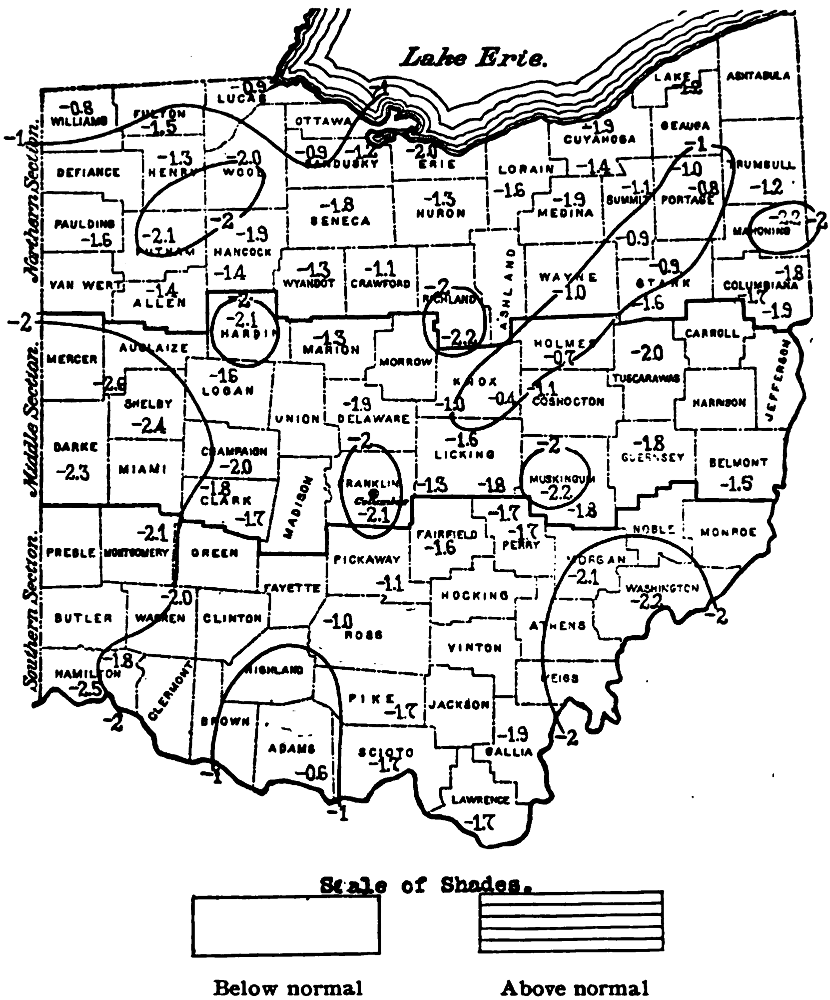


Figure 71. Departure of the precipitation for November from the normal The precipitation was everywhere below the normal. There were but few rainy days and no severely stormy ones, thus making the month unusually favorable for all outside work. The percentage of sunshine was much above the normal.

Snowfall, November, 1912

Figure 72. Total snowfall, November, 1912. The snowfall was generally considerably below the normal for November.

Mean temperature (Normal) December

Figure 73. Normal temperature for December. The normal temperature for this month is 31 degrees, and is below freezing except in the river valleys in the southern portion of the state. An inspection of Figures 1 and 7 show that the average temperature is not below freezing for even the coldest months in the extreme southern points.

Mean temperature, December, 1912

Figure 74. Mean temperature, December, 1912. The warmest period of the month was from the 1st to 6th, inclusive, when the day temperatures ranged from 50 to 70 degrees. A cold wave occurred on the 12th and 13th. The lowest temperature reported was 5° below zero in Logan county. The average temperature for the state was 33.8°

Temperature departures, December, 1912

Figure 75. Departure of the temperature from the normal, December, 1912. The temperature was above the normal in practically all districts and averaged 2.9 degrees above for the state as a whole. The month ranks among the warmest Decembers on record.

Normal precipitation for December

Below 2 2 to 3 3 to 4 4 to 5 over 5

Figure 76. Average precipitation for December. The average precipitation for Ohio in December is 2.92 inches.

Precipitation, December, 1912

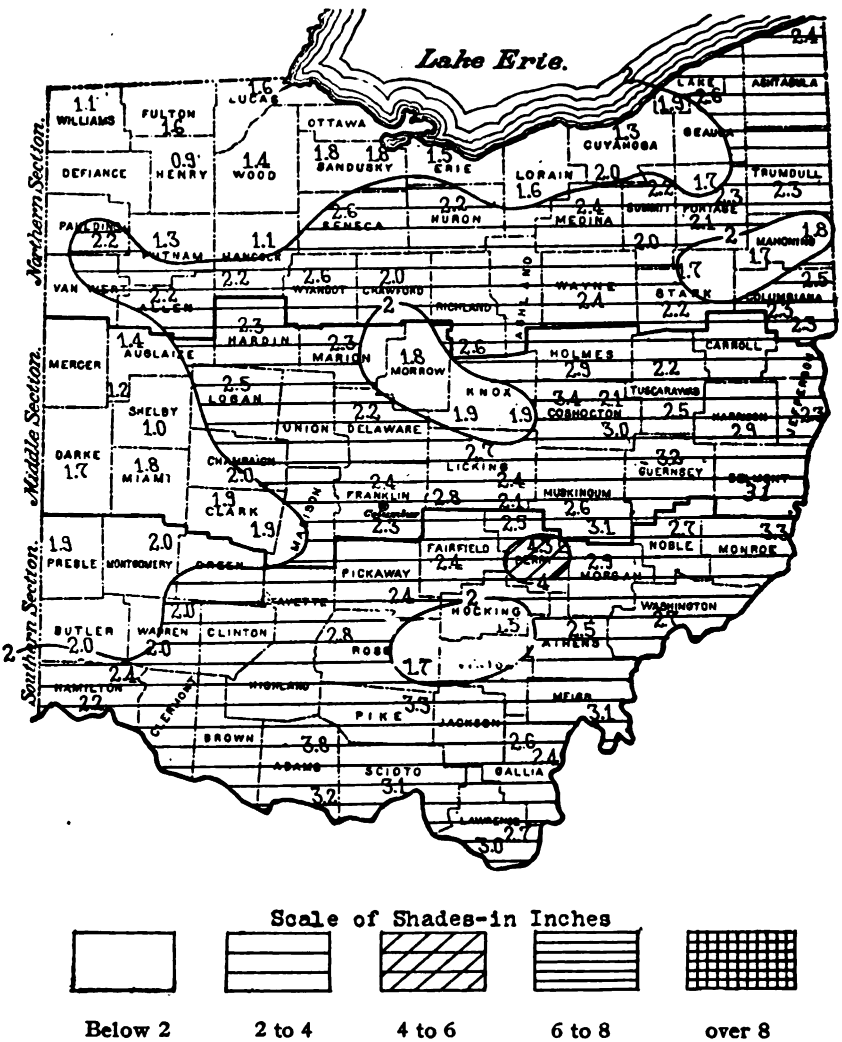


Figure 77. Average precipitation, December, 1912. The precipitation for the month averaged 2.26 inches. The greatest fall was in Milligan, Perry county, and the least in northern and western districts. The number of rainy days was less than usual and the sunshine was greater than usual.

Precipitation departures, December, 1912

Figure 78. Departure of the average precipitation from the normal, December, 1912. The precipitation was less than usual in nearly all sections of the state. The daily falls were generally light and the precipitation was well distributed throughout the month. The average departure for the state was —0.54 inch.

Snowfall, December, 1912

Figure 79. Snowfall, December, 1912. The snowfall was less than normal except in the extreme southern counties. The most of the snow fell on the 18th, 19th, 24th and 27th. In northern counties there was snow on the ground most of the time from the 19th to 28th, inclusive. The average amount of snow for the state was 3.9 inches.

Mean annual temperature

Figure 80. The average annual temperature lines are drawn on this char for each degree. The coolest sections of the state are in the northeastern and northwestern districts, while the warmest are in the extreme southern and southwestern counties. These isothermal lines are very regular in the southern portion of the state, bending to the north when they cross the valleys and to the south over the uplands. There is a large area in the west-central and northwestern counties, however, where the average temperature varies less than 1 degree for a distance of over 100 miles, from Champaign to Ottawa counties. The lowest annual mean temperature is 47.2° in Portage county, and the highest, 55.5° in Scioto county.

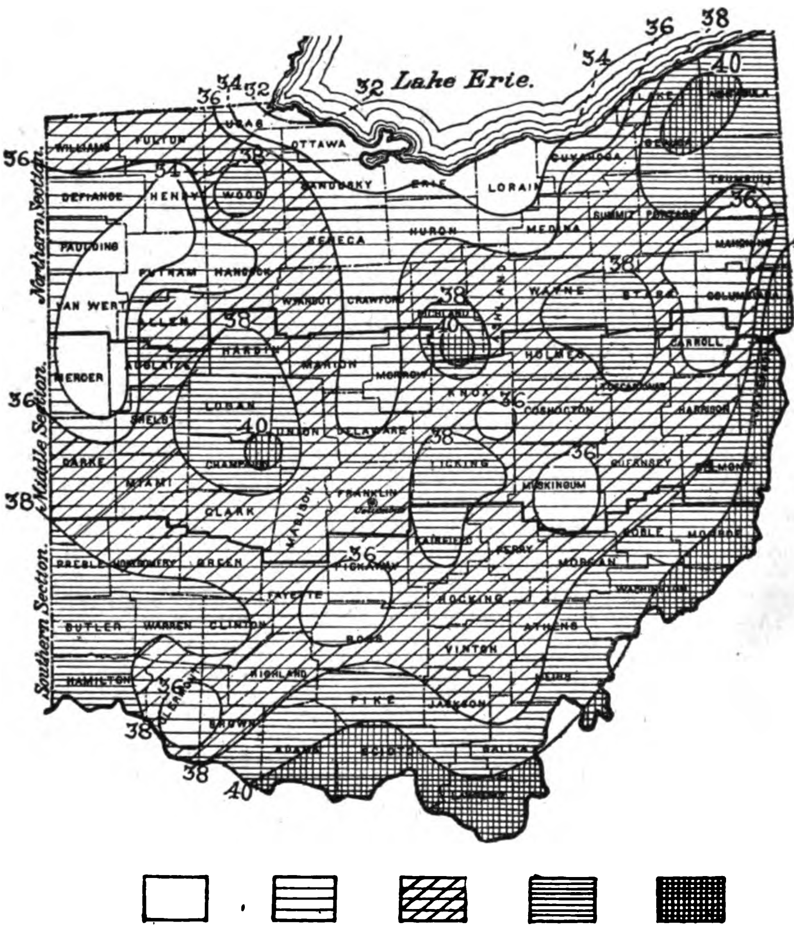
Mean temperature, year 1912

Figure 81. The year as a whole was somewhat cooler than usual. The winter was exceptionally cold and prolonged, the spring was late, the summer was cool, but the fall was mild and pleasant.

Temperature departures, year 1912

Figure 82. The mean temperature was below the normal for the year throughout the state except at one or two stations in extreme southeastern portion.

Average annual precipitation

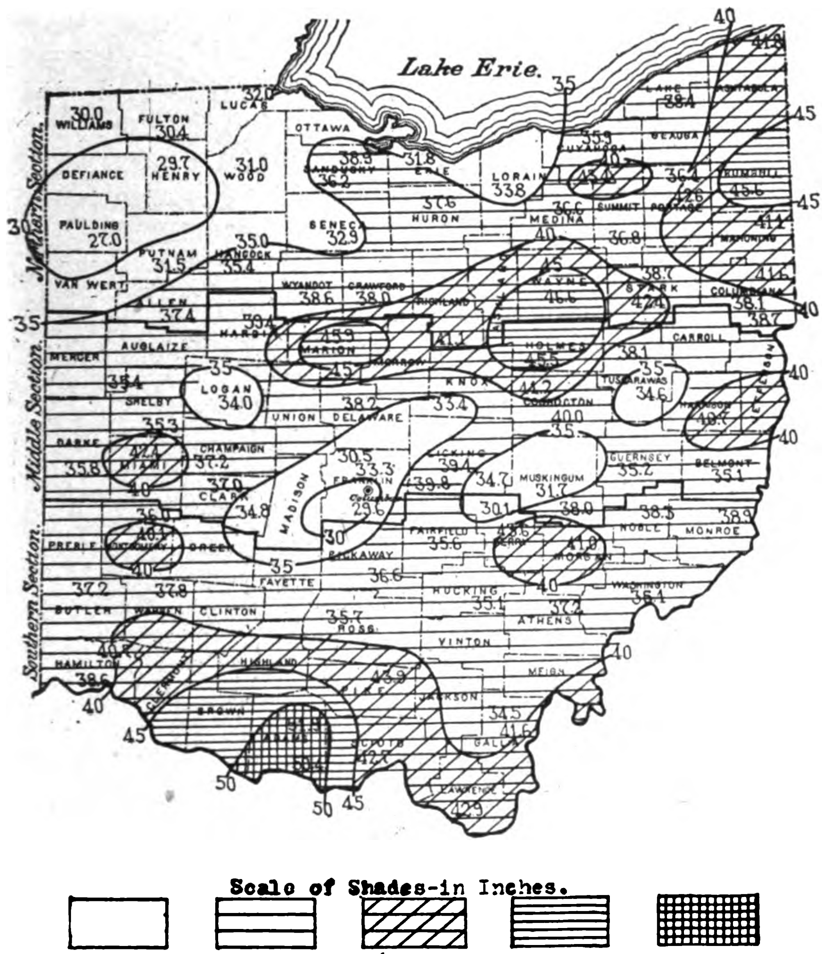


Below 34 | 34-36 | 36-38 | 38-40 | over 40

Scale of shades—in inches

Figure 83. The average annual precipitation for the different sections of Ohio is shown graphically on this chart by means of shaded areas. Lines are drawn for each differences of 2 inches from 34 inches to 40 inches and areas having the same precipitation are given the same shading. The greatest precipitation is along the Ohio river, and the least near the western end of Lake Erie. There is quite a large district in the western portion of the state with a rainfall of less than 34 inches.

Precipitation, year 1912



Below 35 35 to 40 40 to 45 45 to 50 over 50

Figure 84. The precipitation for the year was very irregular. In general it was heaviest in the northeastern and extreme southern counties and lightest in the central and northwestern counties. The wettest months were March, April, July and August, while November was the driest with less than half the usual amount of precipitation.

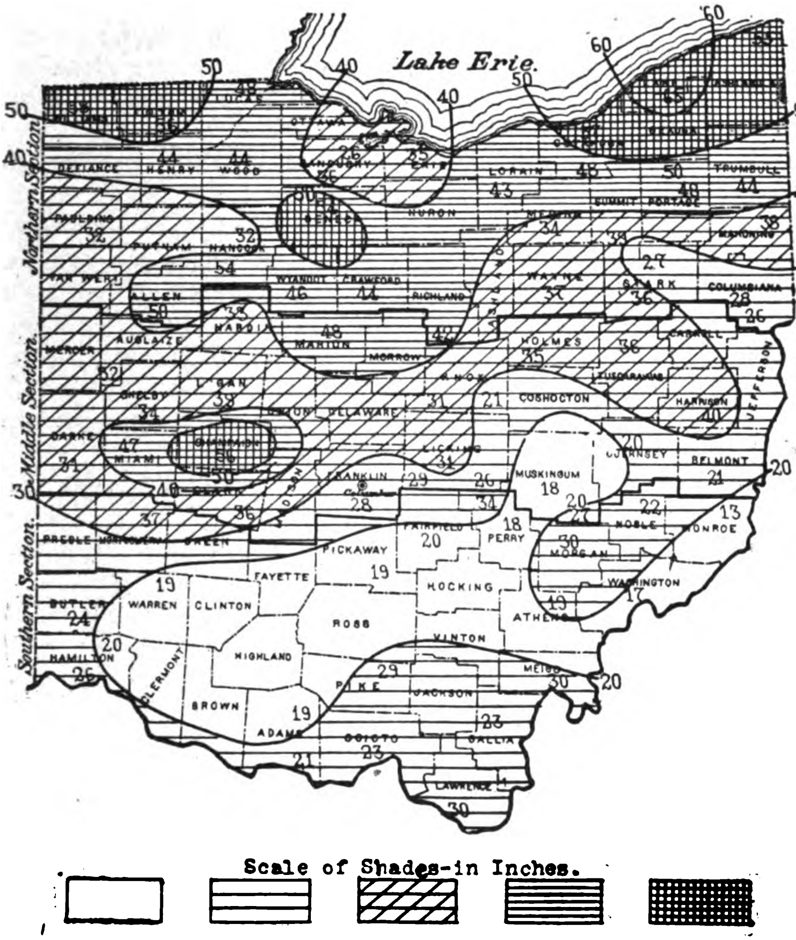
Precipitation departures, year 1912

Scale of Shades.

Below normal | Above nornal

Figure 85. The above chart shows that the precipitation for the year, 1912, was irregularly distributed. It was above the normal in south-central and central-northeast portions.

Snowfall, year 1912



Below 20 | 20 to 30 | 30 to 40 | 40 to 50 | over 50

Figure 86. The snowfall for the year was considerably greater than usual in western counties, but it was slightly below normal in most of the eastern half of the state. The most of the snow fell in January, February and March.

METEOROLOGICAL SUMMARY FOR 1912

By C. A. PATTON

EXPLANATION OF TABLES

The following tables contain statistics of temperature, rainfall, etc., for the year, and are compiled from data obtained from daily observations. T stands for "trace"—less than .01 inch of rainfall. Temperature is given in degrees Fahrenheit.

Table I shows the daily rainfall at the Experiment Station at Wooster during the year in inches and hundredths.

Table II shows the daily mean temperature for each day of 1912 and the monthly mean temperature with the 25 years' average.

Table III gives the monthly mean temperature at the station with the 25 years' average for the same.

Table IV gives the monthly mean rainfall at the station with the 25 years' average for the same.

Table V gives the monthly mean temperature for the state for 1912 with 25 years' average.

Table VI gives the monthly mean rainfall for 1912 with the 25 years' average for the state.

Table VII gives the monthly mean temperature and rainfall for the station and state for 1912 with the 25 years' average.

Table VIII contains the mean temperature, the highest and lowest temperatures, with the range of temperature for each month; the number of clear, fair and cloudy days; the rainfall, snowfall and prevailing direction of wind, for both the station and state for 1912.

Table IX contains the principal points of interest on temperature, rainfall, and state of weather at the station during the year, and a grand summary for 25 years.

Table X contains the principal points of interest on temperature, rainfall, and state of weather for the state during the year and a grand summary for 30 years.

Table XI gives the highest and lowest temperature for each month during the past 25 years, for both the station and state.

Some errors in previous publications of temperature and precipitation, for the state, in tables five, six and ten, are corrected in this report.

NOTES ON THE WEATHER AT THE STATION FOR 1912
SUMMARY BY MONTHS

LATITUDE 40° 47′ 01″, LONGITUDE 81° 55′ 48″
ELEVATION ABOVE THE SEA 1,030 FEET

JANUARY

The mean temperature for January was 16.6°, which is 10.5° below the average for this month. It is also the lowest monthly mean temperature ever recorded at this station, the mercury falling to —24° on the 13th, making this date the coldest on record for this station. The total precipitation for the month was 2.30 inches.

FEBRUARY

The mean temperature for February was 20.5°, which is 5.9° below the average for this month. The first half of month was very cold, followed on the 21st by a severe thunder, sleet and rain storm, accompanied by terrific winds from the northwest. The total precipitation for the month was 1.58 inch.

MARCH

The mean temperature for March was 30.3°, which is 6.9° below the average for the month. The greater part of the month was cold, cloudy and damp, some snow and ice remaining on the ground almost the entire month. The total precipitation was 3.77 inches.

APRIL

The mean temperature for April was 50.0°, which is slightly above the average for this month. The precipitation was far above the average, the total being 5.58 inches. Spring work was much delayed on account of wet weather.

MAY

The mean temperature for May was 61.1°, which is 2.5° above the average for this month. The rainfall was heavy, delaying farm work very late. A very heavy rainfall on the 29th, amounting to 2.38 inches. The total precipitation for the month was 5.65 inches.

JUNE

The mean temperature for June was 64.6°, this being 2.8° below the average for the month. The temperature fell to 31° on the 8th, freezing thin ice. The total precipitation for the month was 2.21 inches, this being 1.79 inch below the average for June.

JULY

The mean temperature for July was 71.6°, this being very near the average for this month for the past twenty-five years. The month was noted for its many electrical storms and very heavy rainfall on the 21st, amounting to 3.74 inches. The total precipitation for the month was 7.46 inches, this being far above the average. July, 1896, with a total fall of 8.05 inches, is the only July on record which surpasses it.

AUGUST

The mean temperature for August was 67.1°, which is slightly below the average for the month. The rainfall was very heavy, amounting to 7.32 inches. A fall of 2.75 inches on the 31st caused high waters and did much damage to growing crops.

SEPTEMBER

The mean temperature for September was 65.6°, which is 1.6° above the average for this month. The highest temperature reached was 93° on the 10th, and the lowest was 30° on the 30th. The total precipitation for the month was 4.41 inches.

OCTOBER

The mean temperature for October was 52.4°, which is 1.2° above the average for the month. Heavy frosts occurred on the 1s and 2nd but most of the vegetation was not killed till the 16th, when the mercury went down to 26°. The total precipitation was 2.18 inches.

NOVEMBER

The mean temperature for November was 41°, which is about the twenty-five-year average for November. The weather for the entire month was unusually fine. The total precipitation was 1.79 inch.

DECEMBER

The mean temperature for December was 33.1°, which is 2.6° above the average for the month. Fine weather continued throughout the month; corn husking and all outside work was well out of the way of cold weather. The total precipitation was 2.35 inches.

METEOROLOGY—TABLE I—RAINFALL

DAILY RAINFALL AND MELTED SNOW FOR 1912 AT THE EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1	....	.10	T	.04	....	....	T	....	.10	....	.20	....	
2	....	.10	....	.90	....	....	.15	.01	T	....	T	.42	2
3	....	.02	....	....	....	....	.41	....	.27	T	....	....	3
4	T	....	.10	....	....	....	....	...	....	.03	T	....	4
5	....	....	....	....	.81	....	....	....	....	....	T	.30	5
6	.05	....	....	....	....	T	....	....	1.56	....	.02	.45	6
7	....	.10	....	.64	.05	....	....	.07	....	....	1.32	....	7
8	.05	....	.18	T	....	....	T	.31	....	....	....	T	8
9	.10	....	....	....	....	....	....	.88	....	.31	.06	....	9
10	T	....	....	....	....	....	.21	.29	....	.16	....	....	10
11	.20	....	.05	....	.27	....	.07	.76	....	....	....	....	11
12	....	.20	.24	.40	.41	T	....	T	....	T	....	....	12
13	....	....	.05	.06	.24	....	....	....	....	....	.06	....	13
14	T	....	.04	.80	.01	....	.18	....	.42	....	.07	....	14
15	.10	....	.68	.60	....	.27	.81	....	.48	....	T	....	15
16	....	....	....	....	1.11	1.12	.02	....	....	....	....	.03	16
17	.10	....	....	.60	.05	T	....	.03	....	....	....	T	17
18	.28	....	....	T	....	T	....	....	.09	.18	....	.12	18
19	.35	.24	....	.02	....	....	....	.43	.02	.60	....	.15	19
20	....	.05	T	....	....	....	....	.03	....	....	....	....	20
21	....	.72	.68	....	....	.33	3.74	.18	....	....	....	....	21
22	.50	....	....	.03	....	....	....	....	.61	.05	....	....	22
23	.02	....	....	T	....	....	....	.52	.86	.80	....	....	23
24	T	....	.64	....	T	....	.83	....	T	.05	.02	....	24
25	T	....	....	....	....	T	....	....	....	....	....	....	25
26	....	....	....	.02	....	....	T	.38	T	....	....	....	26
27	.10	T	.02	....	....	T	....	.15	....	....	T	.20	27
28	T	.05	.26	.02	.30	....	.02	.35	....	....	.02	....	28
29	.40	....	.83	1.30	2.38	....	.90	.18	....	....	....	....	29
30	.06	....	....	.15	.02	.49	....	....	....	....	....	.68	30
31	.10	....	....	....	....	....	.12	2.75	....	T	....	....	31
Total	2.30	1.58	3.77	5.58	5.65	2.21	7.46	7.32	4.41	2.18	1.79	2.35	
Average	.074	.055	.122	.186	.183	.074	.241	.236	.147	.070	.059	.076	

METEOROLOGY—TABLE II—TEMPERATURE

MEAN TEMPERATURE FOR EACH DAY OF 1912 AT THE EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1..............	31.5	21.0	14.0	42.5	54.5	65.5	66.0	58.5	77.0	49.5	49.0	41.0	1
2..............	25.5	17.0	14.0	41.0	64.0	71.0	74.0	63.5	80.5	54.5	33.0	48.0	2
3..............	23.0	5.0	18.5	31.0	59.5	67.5	72.5	57.0	75.0	52.5	34.0	37.0	3
4..............	17.5	8.0	17.0	44.5	61.0	67.0	74.5	54.5	77.5	64.0	39.0	40.5	4
5..............	6.5	7.5	17.5	59.0	63.0	58.0	75.0	58.0	77.0	58.5	52.0	45.0	5
6..............	0.5	12.0	25.0	63.0	70.0	63.0	76.0	62.5	77.5	61.0	59.0	43.5	6
7..............	1.5	13.0	33.5	51.5	67.0	52.5	76.0	66.0	74.5	57.0	50.0	32.5	7
8..............	13.5	12.0	35.5	38.0	63.5	49.5	77.5	71.0	68.5	46.5	42.0	29.5	8
9..............	14.0	3.5	24.0	49.5	56.0	54.5	76.0	73.0	70.5	64.5	39.5	23.5	9
10..............	7.0	—4.0	23.5	46.5	55.5	56.5	78.0	70.0	77.0	66.5	47.0	31.0	10
11..............	8.5	5.5	24.5	51.0	58.0	61.0	75.5	68.5	72.5	68.0	56.5	32.0	11
12..............	3.5	14.5	34.0	60.5	62.0	68.5	72.0	70.0	60.0	61.5	58.5	17.5	12
13..............	—8.0	7.5	29.0	58.0	47.5	58.5	73.5	71.0	62.0	46.0	51.5	23.5	13
14..............	7.0	22.0	30.5	64.0	50.5	64.0	77.5	73.0	70.5	47.5	40.0	34.0	14
15..............	12.0	26.0	36.0	65.5	52.5	70.0	75.5	67.5	69.5	48.0	32.0	38.5	15
16..............	5.5	29.5	33.0	58.0	58.0	71.5	68.5	64.5	63.5	43.5	32.0	40.0	16
17..............	19.0	30.5	43.5	47.5	52.5	71.0	74.0	61.0	61.5	46.0	38.5	39.0	17
18..............	38.0	33.0	42.5	42.5	57.0	64.0	75.0	77.0	66.0	51.5	34.0	40.0	18
19..............	26.5	37.5	45.5	36.5	64.0	60.0	61.0	76.5	57.0	52.0	44.5	31.5	19
20..............	10.0	61.0	39.0	47.0	66.5	62.5	64.5	75.0	60.5	45.0	47.5	30.5	20
21..............	20.0	32.5	27.5	53.0	60.5	61.0	69.0	71.0	63.0	54.0	50.0	28.5	21
22..............	28.5	25.0	24.5	57.0	68.5	58.5	70.0	70.5	64.5	57.5	41.0	25.0	22
23..............	35.0	25.0	31.0	45.0	71.5	62.0	67.5	64.5	59.5	48.5	37.0	20.0	23
24..............	25.5	34.5	32.5	53.5	74.5	67.5	75.0	64.5	62.5	43.0	36.5	28.0	24
25..............	18.0	35.0	23.5	47.0	63.5	69.0	73.0	73.0	66.5	45.0	30.5	31.5	25
26..............	21.5	39.0	31.0	57.0	57.5	70.5	69.0	76.0	61.5	42.0	31.5	32.0	26
27..............	16.0	31.5	34.5	55.0	63.5	70.5	65.5	68.0	47.5	42.5	29.5	32.5	27
28..............	12.5	23.5	35.5	42.0	73.0	74.0	68.0	56.0	51.0	53.0	26.0	26.5	28
29..............	32.5	21.5	35.0	50.0	61.5	77.0	69.0	65.0	50.5	56.5	33.0	30.5	29
30..............	24.0	....	34.0	45.0	59.5	73.5	65.0	61.5	44.0	51.5	35.5	35.5	30
31..............	18.0	....	49.0	....	58.5	....	64.5	72.5	....	47.0	....	37.0	31
Monthly mean.	16.6	20.5	30.3	50.0	61.1	64.6	71.6	67.1	65.6	52.4	41.0	33.1	
25-yr. average.	27.1	26.4	37.2	48.1	58.6	67.4	71.3	69.3	64.0	51.2	39.9	30.5	

METEOROLOGY—TABLE III

MONTHLY MEAN TEMPERATURE FOR TWENTY-FIVE YEARS AT WOOSTER

Temperature in degrees Fahrenheit

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888..........	23.0	28.8	31.7	46.3	57.7	68.9	70.1	67.8	57.1	44.9	40.7	31.4	47.4	1888
1889..........	31.1	22.9	38.7	47.1	57.8	64.5	70.0	66.0	60.8	45.3	39.3	40.7	48.6	1889
1890..........	36.0	36.6	30.9	48.4	56.0	69 8	70.5	65.8	59.6	50.0	41.3	28.8	49.5	1890
1891.........	30.0	34.0	32.0	49.0	52.0	68.0	68.0	71.0	68.0	49.0	38.0	37.0	49.7	1891
1892..........	22.0	33.0	33.0	47.0	57.0	70.0	70.0	69.0	61.0	49.0	38.0	28.0	48.0	1892
1893..........	18.0	28.0	38.8	50.1	57.6	69.3	72.0	67.9	63.2	52.3	37.7	30.9	48.7	1893
1894..........	32.8	26.7	43.5	50 5	57.5	67.9	71.4	69.2	66.1	52.3	36.5	32.9	50.6	1894
1895..........	21.9	17.9	32.4	49.5	59.4	69.9	68.6	70.9	66.5	44.2	40.4	32.8	47.8	1895
1896.........	27.9	29.2	29.8	54.6	64.5	65.6	70.2	68.5	60.6	45.8	44.4	30.6	49.3	1896
1897..........	24.0	30.0	39.3	47.2	53.4	64.3	73.2	67.0	66.7	55.9	40.7	31.8	49.4	1897
1898	31.6	27.4	43.3	45.3	58.2	68.7	74.5	71.1	66.2	52.6	38.4	27.9	50.4	1898
1899..........	26.6	21.3	35.0	52.1	60.0	69.4	70.0	71.0	61.6	55.0	43.2	29.0	49.5	1899
1900..........	30.2	25.0	31.8	47.8	61.5	68.5	72.6	74.0	67.1	58.9	40.6	30.7	50.7	1900
1901..........	28.3	20.0	39.1	45.2	57.9	69.1	75.9	71.6	63.3	51.7	36.6	26.1	48.7	1901
1902.........	26.3	21.4	41.2	46.2	61.2	65.6	73.0	66.4	62.7	53.9	47.3	28.7	49.5	1902
1903..........	24.4	29.0	45.7	48 0	62.2	63.0	71.8	68.8	64.4	58.2	36.8	21.7	49.1	1903
1904..........	18.6	20.5	37.6	42.8	59.4	67.0	69.8	66.7	64.2	50.4	39.6	28.1	47.1	1904
1905..	22.6	19.8	41.2	46.8	59.2	68.0	71.6	70.0	63.8	51.0	38.3	33.1	48.8	1905
1906	35.9	25.8	30.2	51.9	59.9	68.8	71.0	74.2	67.7	51.4	40.4	31.2	50.7	1906
1907...	30.8	24.6	44.9	41.7	52.8	64.6	69.9	68.6	65.0	47.4	38.5	32.1	48.4	1907
1908..........	28.7	26.8	43.1	50.1	62.2	68.1	72.4	69.0	66.4	53.0	41.0	31.7	51.0	1908
1909..........	31.7	33.6	35 9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	50.0	1909
1910..........	26.7	23.8	47.2	50.2	54.7	64.3	72.6	70.9	65.3	54.9	34.8	24.4	49.2	1910
1911..........	31 3	33.8	35.0	46.5	63.5	68.9	71.7	70.6	65.2	51.8	36.7	34.7	50.8	1911
1912..........	16.6	20.5	30.3	50 0	61.1	64.6	71.6	67.1	65.[illegible]	52.4	41.0	33.1	47.8	1912
Average.....	27 1	26.4	37.2	48.1	58.6	67.4	71.3	69 3	64.0	51.2	39.9	30.5	49.2	

METEOROLOGY—TABLE IV

MONTHLY RAINFALL FOR TWENTY-FIVE YEARS AT WOOSTER

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Date
1888........	3.52	2.43	3.34	2.48	3.82	2.31	4.54	4.35	1.92	3.18	4.95	1.39	38.23	1888
1889........	4.33	2.42	2.13	1.58	2.97	4 86	6.73	1.98	4.05	1.36	3.53	3.93	39.87	1889
1890........	4.71	6.20	4.37	3.10	6.01	5.57	2.67	4.66	5.12	7.45	2.61	1.74	54.21	1890
1891........	2.74	4.83	3.71	1.66	2.24	7.13	3.28	1.85	0.94	1.33	5.73	2.92	38.36	1891
1892........	2.67	2.67	3.38	2.44	7.69	7.89	4.73	2.69	3.20	0.37	2.06	1.74	41.46	1892
1893........	4.01	6.33	1.89	5.66	6.28	2.51	1.38	1.53	1.85	5.18	2.49	1.50	40.61	1893
1894........	2.19	3.37	2.36	1.74	4.41	2.23	1.38	0.76	4.07	2.53	2.41	3.15	30.60	1894
1895........	3.92	1.00	1.98	1.69	1.38	4.20	2.19	2.30	3.92	1.15	4.21	3.51	31.45	1895
1896........	1.73	2.27	3.67	3.34	3.41	3.98	8.05	1.96	5.16	0.71	1.78	2.41	38.47	1896
1897........	2.82	2.64	2.81	2.75	4.97	2.98	3.89	3.86	0.29	0.89	5.76	2.50	36.16	1897
1898........	4.10	2.27	6.44	2.56	4.60	2.70	6.79	5.53	2.15	4.25	4.14	2.29	47.85	1898
1899........	3.29	1.64	3.95	1.28	4.42	1.95	3.73	0.53	5.56	2.21	1.59	2.78	32.93	1899
1900........	2.78	2.74	2.25	1.70	2.23	3.71	5.65	5.97	2.19	2.10	4.30	0.99	36.61	1900
1901........	1.56	1.20	3.09	2.46	4.32	4.82	3.32	3.58	5.64	0.81	1.62	3.47	35.91	1901
1902........	0.63	0.83	2.99	1.46	2.57	5.55	5.26	1.87	3.49	1.52	2.62	4.07	32.86	1902
1903........	3.54	3.69	3.29	4.55	1.59	3.69	4.61	6.58	2.07	2.63	2.25	1.95	40.44	1903
1904........	5.27	3.90	6.22	6.59	4.45	1.67	4.93	2.03	2.27	0.87	0.40	2.68	41.28	1904
1905........	1.83	1.36	2.61	2.51	5.97	7.50	5.14	4.47	5.10	2.32	2.04	2.08	42.93	1905
1906........	1.93	1.06	3.57	2 27	2.98	3.81	4.93	7.38	5.16	3.55	2.39	3.77	42.80	1906
1907........	6.92	1.09	5.80	2.69	3.48	3.81	3.96	2.04	3.13	2.34	1.33	3.41	40.00	1907
1908........	1.96	3.89	5.02	3.64	4.56	2.17	3.44	3.17	0.73	1.22	1.09	3.05	33.94	1908
1909........	2 95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.91	2.55	44.22	1909
1910........	5.29	4.41	1.00	3.22	4.87	2.57	1.12	0.95	2.59	5.24	2.36	2.29	35.91	1910
1911........	4.13	2.25	3.26	3.71	2.45	3.78	3.36	5.19	6.53	5.45	2.50	4.54	47.15	1911
1912........	2.30	1.58	3.77	5.58	5.65	2.21	7.46	7.32	4.41	2.18	1.79	2.35	46.60	1912
Average...	3.25	2.85	3.44	2.08	4.06	4.00	4.26	3.51	3.33	2.52	2.75	2.68	39.63	

METEOROLOGY—TABLE V

MONTHLY MEAN TEMPERATURE FOR TWENTY-FIVE YEARS FOR THE STATE

Temperature in degrees Fahrenheit

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888........	24.3	30.5	34.2	49.2	58.8	70.4	72.1	70.4	60.3	47.9	42.9	33.3	49.5	1888
1889........	33.3	25.8	40.2	49.9	60.2	66.7	72.5	69.1	62.9	47.9	41.0	43.8	51.1	1889
1890........	38.8	39.4	34.5	51.3	59.2	73.3	73.0	68.8	62.1	52.7	42.2	31.2	52.2	1890
1891........	33.0	36.0	35.0	52.0	58.0	71.0	69.0	70.0	67.0	51.0	40.0	39.0	51.8	1891
1892........	24.0	35.0	35.0	49.0	59.0	73.0	73.0	71.0	64.0	52.0	38.0	29.0	50.2	1892
1893........	18.0	29.0	38.0	50.2	58.3	70.6	74.5	70.7	65.2	53.7	39.3	32.7	50.0	1893
1894........	33.7	28.9	45.1	50.6	60.0	71.3	74.3	71.2	67.8	53.9	37.5	33.9	52.4	1894
1895........	23.4	19.6	35.5	51.7	61.1	72.0	71.6	73.5	69.0	46.9	41.9	33.9	50.0	1895
1896........	29.4	30.5	32.4	56.9	67.9	69.5	73.2	71.8	62.7	49.0	45.1	32.9	51.8	1896
1897........	25.5	32.4	41.5	49.3	56.3	68.1	75.5	69.4	66.9	58.1	42.2	32.8	51.5	1897
1898........	32.4	30.0	45.0	47.2	61.0	71.9	76.0	73.5	67.8	54.1	38.8	28.8	52.2	1898
1899........	27.8	21.6	36.9	53.3	63.3	71.5	74.1	73.7	64.1	57.4	43.9	30.2	51.5	1899
1900........	31.1	26.0	32.9	50.1	62.9	69.8	74.1	76.3	69.3	60.5	41.6	31.6	52.2	1900
1901........	29.2	21.1	39.5	46.7	59.0	70.9	78.1	73.1	64.8	53.8	37.7	27.9	50.2	1901
1902........	27.3	22.3	41.9	48.2	62.6	66.9	74.0	68.9	63.6	54.6	48.5	29.4	50.7	1902
1903........	27.1	29.9	46.7	49.9	63.9	64.4	72.9	70.7	65.6	54.0	37.2	23.4	50.5	1903
1904........	20.7	22.9	39.7	44.4	60.7	68.4	71.4	68.8	65.5	52.2	40.5	28.0	48.6	1904
1905........	22.7	20.8	42.7	48.5	60.7	69.2	73.0	71.7	65.3	52.6	39.6	32.9	50.0	1905
1906........	35.7	27.3	31.3	52.1	61.3	69.8	72.1	74.6	68.9	52.7	41.1	32.3	51.6	1906
1907........	32.2	26.0	45.9	42.5	54.5	65.6	72.6	69.5	65.5	48.8	39.1	33.0	49.6	1907
1908........	29.1	27.7	43.4	51.0	62.8	69.2	73.9	71.2	68.0	54.1	41.7	33.1	52.1	1908
1909........	32.2	34.7	37.3	49.1	58.7	70.1	70.7	71.9	63.2	48.8	48.9	25.4	50.9	1909
1910........	27.6	25.5	48.2	51.5	56.0	65.9	73.8	71.4	66.3	56.7	36.3	25.5	50.4	1910
1911........	32.8	34.5	37.4	47.7	66.3	70.9	74.0	72.5	67.5	53.3	37.6	36.3	52.6	1911
1912........	17.9	22.4	32.9	51.9	62.5	66.6	73.4	69.2	67.4	54.8	42.2	33.8	49.6	1912
Average...	28.4	28.0	38.9	49.8	60.6	69.5	73.3	71.3	65.6	52.9	41.0	31.8	50.9	

METEOROLOGY—TABLE VI

MONTHLY RAINFALL FOR TWENTY-FIVE YEARS FOR THE STATE

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Date
1888........	3.65	1.74	3.55	1.99	3.77	3.41	4.40	5.16	2.27	3.98	4.25	1.47	39.64	1888
1889	3 13	1.35	1.38	1.79	3.71	4.13	4.19	1.50	3.62	1.78	4.02	2.81	33.41	1889
1890........	4.94	5.25	5.29	3.45	5.52	4.50	1.99	4.66	5 56	4.27	2.53	2.37	50.33	1890
1891........	2.82	4.91	4.19	2.13	2.20	4.82	3.82	3 07	1.50	1.76	5.00	2.39	38.61	1891
1892........	2.11	3.03	2.86	3.32	6.32	5.61	3.80	2.99	2.36	0.73	2.32	1.71	37.16	1892
1893........	2.56	5.13	2.09	6.37	4.97	3.34	2.49	2.17	1.57	4.24	2.09	2.61	39.63	1893
1894........	2.14	2.79	2.16	2.31	4.00	2.65	1.56	1.67	3.31	2.01	2.17	2.98	29.75	1894
1895........	4.00	0.69	1.59	2.11	1.80	2.47	2.00	2.96	1.66	1.22	4.11	3.85	28.46	1895
1896........	1.67	2 21	3.34	2.78	2.67	4.81	8.11	3.38	5.13	1.29	2.63	1.65	39.58	1896
1897........	1.93	3.64	5 17	3.27	3.93	2.85	4.65	2.72	0.78	0.64	6.62	2.39	38.59	1897
1898........	5.25	2.32	6.23	2.38	4.10	2.86	3.98	4.50	2.56	3.72	3.17	2.71	43 78	1898
1899........	3.01	2.11	4.64	1.61	4.32	2.96	4.17	1.82	2.68	2.14	1.72	3 16	34.32	1899
1900........	2.37	3.46	2.35	1.89	2.40	3.01	4.62	3.68	1.76	1.89	4 15	1.24	32.82	1900
1901........	1.70	1.24	2.66	3.40	3.96	4.44	2.72	3.33	2.86	0.73	1 53	3.79	32.36	1901
1902........	1.42	0.88	2.76	2.21	3.09	7.48	4.69	1.67	4.55	2.28	2.60	3.95	37.58	1902
1903........	2.36	4.95	3 51	4 01	2.82	4.02	3.67	3.20	1.52	2.62	2.10	2.07	36.85	1903
1904........	3.85	2.69	5.67	3.53	3.79	2.88	4.13	2.74	1.95	1.50	0.37	3.09	36.19	1904
1905........	1.73	1.58	2.50	3.10	5.63	4.72	3.93	4.46	2.36	3.65	2.63	2.29	39 08	1905
1906........	1.98	1.16	3.97	1.89	2.17	3.42	5.14	4.77	2.92	3.19	2.59	3.68	36.88	1906
1907........	6.06	0.85	5.55	2.74	3.47	4.57	5.36	2.48	3.92	2.76	1.93	3.16	42.85	1907
1908........	1.82	4.10	5.43	3.71	4.72	2.51	4 08	2.59	0.58	1 17	1.06	2.33	34.10	1908
1909........	3.24	5 39	2.77	4.13	4.72	5.86	3.76	3 56	1.78	2.31	2.52	2.61	42.65	1909
1910........	4.48	4.05	0.26	3.49	3.80	2.66	3.17	1.58	4.05	4.19	1.89	2.41	36.03	1910
1911........	3.90	1.95	2.33	4.35	1.69	3.92	2.40	5.39	4.87	4.99	2.91	3.93	42.63	1911
1912........	2.12	2.08	4.17	4 47	3.12	3.17	5.70	4.08	3.11	2 44	1.10	2.26	37.82	1912
Average...	2.97	2.78	3.46	3.06	3 71	3.88	3.94	3.21	2.79	2.46	2.72	2.68	37.66	

METEOROLOGY—TABLE VII

MEAN TEMPERATURE AND RAINFALL AT THE STATION AND FOR THE STATE, 1912, AND FOR TWENTY-FIVE YEARS

Temperature in degrees Fahrenheit. Rainfall in inches.

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mean temperature at the Station, 1912	16.6	20.5	30.3	50 0	61.1	64.6	71.6	67.1	65.6	52.4	41.0	33 1	47.8
Twenty-five years average temperature at the Station	27.1	26.4	37.2	48.1	58.6	67.4	71.3	69.3	64.0	51.2	39.9	30.5	49.2
Mean temperature for the state, 1912	17.9	22.4	32.9	51.9	62.5	66.6	73.4	69.2	67.4	54.8	42.2	33.8	49.6
Twenty-five years average temperature for the state	28.4	28.0	38.9	49.8	60.6	69.5	73.3	71.3	65.6	52.9	41.0	31.8	50.9
Rainfall at the Station, 1912	2.30	1.58	3.77	5.58	5.65	2.21	7.46	7.32	4.41	2.18	1.79	2.35	3.88
Twenty-five years average rainfall at the Station	3.25	2.85	3.44	2.08	4.06	4.00	4.26	3.51	3.33	2.52	2.75	2.68	3.30
Rainfall for the state, 1912	2.12	2.08	4.17	4.47	3.12	3.17	5.70	4.08	3.11	2.44	1.10	2.26	3.15
Twenty-five years average rainfall for the state	2.97	2.78	3.48	3.06	3.71	3.88	3.94	3.21	2.79	2.46	2.72	2.68	3.14

METEOROLOGY—TABLE VIII

SUMMARY BY MONTHS FOR 1912

	Temperature											Number of days				Precipitation in inches			
	Mean	Highest	Date	Lowest	Date	Range	Mean daily range	Greatest daily range	Date	Least daily range	Date	Clear	Fair	Cloudy	Rainfall .01 or more	Monthly rainfall	Average daily rainfall	Monthly snowfall	Prevailing wind
AT THE STATION																			
January	16.6	44	18	—24	13	68	17.7	37	8	6	23	3	6	22	13	2.30	.074	8.75	N. W.
February	20.5	55	26	—16	10	71	20.4	43	13	9	19	8	4	17	9	1.58	.055	11.75	N. W.
March	30.3	68	31	6	1	62	19.7	38	31	7	22	7	3	21	12	3.77	.122	8.45	N. W.
April	50.0	78	12	23	19	55	24.0	42	11	10	*27	13	6	11	14	5.58	.186	4.00	N. W.
May	61.1	86	23	36	13	50	22.9	35	10	11	21	20	4	7	11	5.65	.182	....	S. W.
June	64.6	88	29	31	8	57	24.6	38	11	10	17	18	4	8	4	2.21	.074	....	S. W.
July	71.6	90	*14	51	19	39	21.8	29	15	12	29	12	15	4	12	7.46	.241	....	S. W.
August	67.1	89	18	41	5	48	21.3	34	5	10	29	9	12	10	16	7.32	.236	....	S. W.
September	65.6	93	10	30	30	63	22.7	39	9	9	*22	18	6	6	9	4.41	.147	....	S. W.
October	52.4	82	11	26	*16	56	26.3	38	*6	13	22	17	6	8	8	2.18	.070	....	S. W.
November	41.0	68	*6	18	*16	50	18.1	28	16	7	*15	8	6	16	8	1.79	.059	.50	S. W.
December	33.1	58	6	8	12	50	17.7	30	1	6	3	7	6	18	8	2.35	.076	3.50	S. W.
Sums and averages	47.8	93	Sept. 10	—24	Jan. 13	56	21.4	43	Feb. 13	6	Dec. *3	40	77	148	124	46.60	.127	36.95	S. W.
FOR THE STATE																			
January	17.9	58	23	—37	13	95	....	51	..	..	..	8	8	15	11	2.12	.068	10.60	W
February	22.4	68	26	—25	10	93	....	52	..	..	..	10	8	11	9	2.08	.072	9.80	W
March	32.9	80	31	—3	16	83	....	48	..	..	..	9	7	15	12	4.17	.135	6.90	N. W.
April	51.9	89	12	15	3	74	....	51	..	..	..	12	8	10	12	4.47	.149	2.10	S. W.
May	62.5	91	*22	31	13	60	....	46	..	..	..	15	9	7	10	3.12	.101	T	S. W.
June	66.6	93	29	28	8	65	....	47	..	..	..	16	9	5	7	3.17	.106	....	S. W.
July	73.4	101	15	42	19	59	....	37	..	..	..	9	15	7	11	5.70	.184	....	S. W.
August	69.2	95	18	40	*4	55	....	42	..	..	..	10	13	8	13	4.08	.132	....	S. W.
September	67.4	99	5	29	27	70	....	45	..	..	..	16	8	6	8	3.11	.104	....	S. W.
October	54.8	93	11	23	*26	70	....	55	..	..	..	18	6	7	6	2.44	.079	T	S. W.
November	42.2	82	6	8	28	74	....	50	..	..	..	13	7	10	5	1.10	.037	.60	S. W.
December	33.8	74	10	—5	12	79	....	51	..	..	..	10	8	13	8	2.26	.073	3.90	S. W.
Sums and averages	49.6	101	July 15	—37	Jan. 13	73	....	55	..	..	..	146	106	114	112	37.82	.103	33.90	S. W.

*On other dates also.

METEOROLOGY—TABLE IX

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-FIVE YEARS AT WOOSTER

	1888	1889	1890	1891	1892	1893	1894	1895
AT........................	WOOSTER					EXPERIMENT STATION		
Mean temperature	47.4°	48.6°	49.5°	49.7°	48°	48.7°	50.6°	47.8°
Highest temperature	....	91.5° *1	94.5° Aug. 3	99° Aug. 8	98° July 25	95° *5	98° July 19	98° June 4
Lowest temperature	—5° Feb. 9	—5° *2	1° Mar. 2	0° Mar. 1	—20° Jan. 20	—9° Jan. 11	—7° Dec. 28	—6° *8
Range of temperature	....	96.5°	93.5°	99°	118°	104°	105°	104°
Mean daily range of temperature	....	18.7°	18.9°	21°	19°	20.2°	22.9°	21.8°
Greatest daily range of temperature	....	42° Apr. 23	41° Jan. 13	42° Sept. 23	46° July 17	45° Aug. 9	45° July 31	55° Oct. 6
Least daily range of temperature	....	2° Jan. 6	4.5° *3	4° Feb. 8	4° *4	3° *6	4° *7	1° Nov. 22
Number of clear days	....	125	109	116	116	96	127	125
Number of fair days	....	103	119	110	123	164	154	117
Number of cloudy days	....	137	137	125	98	105	84	123
Number of days rain fell	....	119	149	119	119	129	130	102
Total yearly rainfall	38.23 inches	39.87 inches	54 21 inches	38.36 inches	41.46 inches	40.61 inches	30.60 inches	31.45 inches
Greatest monthly rainfall	4.51 inches	6.73 in. July	7.45 in. Oct.	4.26 in. June	7.89 in. June	6.33 in. Feb.	4.41 in. May	4.21 in. Nov.
Least monthly rainfall	1.39 inch	1.36 in. Oct.	1.74 in. Dec.	1.95 in. April	1.37 in. Oct.	1.38 in. July	0.76 in. Aug.	1.00 in. Feb.
Prevailing direction of wind	S.	S.	S.	S.	S. W.	S. W.	S. W.	W.

*1 July 10 and Sept. 1. *2 Feb. 23 and 24. *3 Jan. 8 and Sept. 10. *4 March 5, Nov. 1, 3 and 25, Dec. 1 and 18. *5 July 7, 25 and Sept. 7. *6 Jan. 24, Feb. 11, May 26. *7 Dec. 1 and 21. *8 Jan. 12, 13, and Feb. 5.

METEOROLOGY—TABLE IX. Continued

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-FIVE YEARS AT WOOSTER

	1896	1897	1898	1899	1900	1901	1902	1903	1904
AT	EXPERIMENT STATION								
Mean temperature	49.3°	49.4°	50.4°	49.5°	50.7°	48.7°	49.5°	49.1°	47.1°
Highest temperature	93° Aug. 9	96° *10	96° July 3	95° Aug. 20	95° July 4	95° *12	97° May 4	94° *14	92° July 17
Lowest temperature	—6° Feb. 19	—18° Jan. 26	—9° Feb. 2	—21° Feb. 10	—10° Feb. 27	—11° Dec. 21	—9° Feb. 5	—9° Feb. 19	—21° Jan. 5
Range of temperature	99°	114°	105°	116°	105°	106°	106°	103°	113°
Mean daily range of temperature	19°	21.5°	20.3°	22.9°	20.6°	20.1°	21.3°	21.6°	21.5°
Greatest daily range of temperature	43° May 8	49° Oct. 5	50° Nov. 14	52° Oct. 24	43° May 6	43° April 30	45° May 4	48° Nov. 8	48° Dec. 28
Least daily range of temperature	3° *9	0° Feb. 6	5° *11	3° Feb. 18	2° Nov. 20	2° April 20	4° *13	3° *15	0° Dec. 25
Number of clear days	130	124	133	126	149	152	183	148	149
Number of fair days	106	123	104	114	68	66	49	58	47
Number of cloudy days	130	115	128	125	118	147	133	159	170
Number of days rain fell	134	123	134	116	132	142	140	121	136
Total yearly rainfall	38.47 inches	36.16 inches	47.85 inches	32.93 inches	36.61 inches	35.91 inches	32.86 inches	40.44 inches	41.28 inches
Greatest monthly rainfall	8.05 in. July	5.76 in. Nov.	6.79 in. July	5.56 in. Nov	5.97 in. Nov.	5.64 in. Nov.	5.55 in. June	6.58 in. Aug.	6.59 in. April
Least monthly rainfall	0.71 in. Oct.	0.29 in. Sept.	2.15 in. Sept.	0.53 in. Aug.	0.99 in. Dec.	0.81 in. Oct.	0.63 in. Jan.	1.59 in. May	0.40 in. Nov.
Prevailing direction of wind	S. W.	S. W.	N. W.	N. S. W.	S. W.	S. W.	S. W.	S. W.	S. W.

*9 Jan. 10 and March 8. *10 July 5 and 6. *11 Jan. 21, March 2 and Dec. 18. *12 July 1, 22 and 28.

METEOROLOGY—TABLE IX. Concluded

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-FIVE YEARS AT WOOSTER

	1905	1906	1907	1908	1909	1910	1911	1912	Summary for twenty-five years
AT	EXPERIMENT STATION								
Mean temperature	48.8°	50.7°	48.4°	51.0°	50.0°	49.2°	50.8°	47.8°	49.2°
Highest temperature	92° July 17	92° June 9	90° Aug. 12	95° *17	90° Sept. 14	94° *19	101° July 4	93° Sept. 10	101° July 4, '11
Lowest temperature	—12° Feb. 14	—14° Feb. 7	—14° Jan. 20	—3° Feb. 9	—11° Jan. 13	—12° Feb. 19	—11° Jan. 4	—24° Jan. 13	—24° Jan. 13, 12
Range of temperature	104°	106°	104°	98°	101°	106°	112°	117°	125°
Mean daily range of temperature	20.8°	20.6°	20.8°	23°	21.4°	23.1°	21.5°	21.4°	21°
Greatest daily range of temperature	42° *16	40° April 18	42° Jan. 20	49° Sept. 18	43° *18	51° April 14	45° Mar. 25	43° Feb. 13	55° Oct. 6, '95
Least daily range of temperature	2° Dec. 18	2° Jan. 18	4° Aug. 6	5° Dec. 13	3° Dec. 14	3° Nov. 16	4° Mar. 28	6° Jan. 23	0° *20
Number of clear days	144	130	109	141	114	127	110	140	130
Number of fair days	44	60	58	78	76	67	84	75	90
Number of cloudy days	177	175	198	147	175	171	170	148	141
Number of days rain fell	118	142	138	117	144	133	142	124	130
Total yearly rainfall	42.93 inches	42.80 inches	40.00 inches	33.94 inches	44.22 inches	35.91 inches	47.15 inches	46.60 inches	39.63 inches
Greatest monthly rainfall	7.50 in. June	7.38 in. Aug.	6.92 in. Jan.	5.02 in. Mar.	6.44 in. Jan.	5.29 in. Jan.	6.53 in. Sept.	7.46 in. July	8.05 in. July, '96
Least monthly rainfall	1.36 in. Feb.	1.06 in. Feb.	1.09 in. Feb.	0.73 in. Sept.	1.73 in. Sept.	0.95 in. Aug.	2.25 in. Feb.	1.58 in. Feb.	.29 in. Sept. '97
Prevailing direction of wind	S.	S.	N. S. W.	S. W.	S. W.	S. W.	N. W.	S. W.	S. W.

*13 Jan. 22 and April 28. *14 July 4 and 9. *15 Jan. 4, Nov. 27 and Dec. 6. *16 April 9 and May 2. *17 Aug. 3, Sept. 24 and 25. *18 May 8 and October 9.
*19 July 25 and Aug. 15 and 16. *20 Feb. 6, 1897, and Dec. 25, 1904.

METEOROLOGY—TABLE X

SUMMARY BY YEARS AND GRAND SUMMARY FOR THIRTY YEARS FOR THE STATE

FOR THE STATE	1883	1884	1885	1886	1887	1888	1889	1890
Mean temperature	49.4°	50.6°	48.0°	49.6°	52.0°	49.5°	51.1°	52.2°
Highest temperature	98° Aug. 22	98° *1	101° July 21	98.6° July 18	108° July 18	102° Aug. 3	99.5° Aug. 31	103.1° Aug. 3
Lowest temperature	−17.2° Jan. 22	−34° Jan. 25	−31.5° Jan 29	−21.5° Jan. 12	−21° Jan. 7	−15° Jan. 27	−13.5° Feb. 24	−4° Mar. 7
Range of temperature	115.5°	133°	132°	120.1°	29°	117°	113°	107.1°
Greatest daily range of temperature	55.2° Mar. 18	50° *2	58.5° Jan. 30	57° Dec. 11	57° Dec. 11	50°	53° Mar. 30	48.5 Apr. 11
Average number of days rain fell	146	145	148	131	121	125	118	149
Mean yearly rainfall	44.98 inches	40.19 inches	30.08 inches	36.71 inches	33.63 inches	39.64 inches	33.41 inches	50.33 inches
Mean daily rainfall	.123 inch	.110 inch	.082 inch	.101 inch	.092 inch	.108 inch	.092 inch	.138 inch
Prevailing direction of wind	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.
	1891	**1892**	**1893**	**1894**	**1895**	**1896**	**1897**	**1898**
Mean temperature	51.8°	50.2°	50.0°	52.7°	50.0°	51.8°	51.5°	52.2°
Highest temperature	101° Aug. 10	103° July 25	102° July 19	105° *4	106° July 20	103° Apr. 17	113° July 4	105° July 1
Lowest temperature	−8° Mar. 2	−25° Jan. 20	−24° Jan. 11	−27° Dec. 29	−24° Feb. 6	−18° *6	−27° Jan. 26	−20° Feb. 3
Range of temperature	109°	128°	126°	132°	130°	121°	140°	125°
Greatest daily range of temperature	50° *3	51° Sept. 25	54.6°	60° Oct. 19	59° *5	53° Mar. 25	67° *7	....
Average number of days rain fell	120	121	113	100	89	124	110	121
Mean yearly rainfall	38.61 inches	37.16 inches	39.63 inches	29.75 inches	28.46 inches	39.58 inches	38.59 inches	43.78 inches
Mean daily rainfall	.106 inch	.102 inch	.109 inch	.081 inch	.078 inch	.108 inch	.106 inch	.119 inch
Prevailing direction of wind	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.

*1 Sept. 28 and Oct. 1. *2 Sept. 5 and Dec. 4. *3 April 27 and 30. *4 July 18 and 19. *5 Jan. 15 and March 29. *6 Feb. 20 and 21. *7 Sept. 25 and 26.

METEOROLOGY—TABLE X. Concluded

SUMMARY BY YEARS AND GRAND SUMMARY FOR THIRTY YEARS FOR THE STATE

FOR THE STATE	1899	1900	1901	1902	1903	1904	1905	1906
Mean temperature	51.5°	52.2°	50.2°	50.7°	50.5°	48.6°	50.0°	51.6°
Highest temperature	105° Sept. 6	103° *8	109° July 22	100° July 8	104° July 25	99° *10	100° July 10	101° Aug. 21
Lowest temperature	−39° Feb. 10	−20° *9	−20° Feb. 23	−17° Feb. 14	−20° Feb. 19	−30° Jan 4	−20° Feb. 3	−23° Feb. 6
Range of temperature	144°	123°	129°	117°	124°	129°	120°	124°
Greatest daily range of temperature	....	57° Feb. 9	61° Dec. 14	56° May 4	60° Sept. 25	54° Jan. 5	57° May 24	54° Oct. 13
Average number of days rain fell	107	107	107	114	111	117	118	124
Mean yearly rainfall	34.32 inches	32.82 inches	32.36 inches	37.58 inches	36.85 inches	36.19 inches	39.08 inches	36.88 inches
Mean daily rainfall	.094 inch	.090 inch	.089 inch	.103 inch	.101 inch	.099 inch	.107 inch	.101 inch
Prevailing direction of wind	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.

	1907	1908	1909	1910	1911	1912	Summary for thirty years
Mean temperature	49.6°	52.1°	50.9°	50.4°	52.6°	49.6°	50.7°
Highest temperature	98° July 22	104° Aug. 3	97° July 30	100° Aug. 17	107° July 4	101° July 15	113° July 4, '97
Lowest temperature	−19° Feb. 6	−22° Feb. 9	−20° Dec. 30	−25° Feb. 19	−19° Jan. 4	−37° Jan. 13	−39° Jan. 10, '99
Range of temperature	117°	126°	117°	125°	126°	138°	152°
Greatest daily range of temperature	57° Feb. 13	60° Oct. 5	51°	....	....	....	67° Sept. '97
Average number of days rain fell	129	111	124	112	127	112	120
Mean yearly rainfall	42.85 inches	34.10 inches	42.65 inches	36.03 inches	42.63 inches	37.82 inches	37.56 inches
Mean daily rainfall	.117 inch	.093 inch	.117 inch	.099 inch	.117 inch	.104 inch	.103 inch
Prevailing direction of wind	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.

*8 July 4, Aug. 6 and 10. *9 Jan. 26 and Feb. 27. *10 July 17 and Sept. 29.

METEOROLOGY—TABLE XI

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-FIVE YEARS FOR WOOSTER

Date	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	..	-5	..	-1	..	8	..	19	..	31	..	42	..	43	..	41	..	31	..	27	..	21	..	9
1889	54	12	54	-5	71	16	80	21	90	30	87	38	92	49	90	45	92	37	76	23	65	16	65	18
1890	66	5	65	14	60	1	74	23	83	30	88	46	94	45	95	40	88	38	81	30	66	24	48	15
1891	51	12	60	3	61	0	83	21	82	28	89	44	89	49	99	53	98	42	88	25	71	10	58	16
1892	54	-20	54	6	65	10	76	28	86	38	90	56	98	48	92	49	88	36	81	25	67	16	61	-2
1893	51	-9	47	-2	75	10	83	24	84	36	92	45	95	47	93	37	95	28	85	24	66	15	62	6
1894	56	1	64	-1	75	14	92	24	83	35	93	37	98	41	96	41	93	36	80	28	65	31	57	-7
1895	54	-6	60	-6	59	9	80	21	94	27	98	35	92	42	94	42	93	34	73	19	72	18	61	-2
1896	53	-2	58	-6	65	4	89	19	86	44	87	39	92	45	93	41	92	34	71	21	69	13	56	1
1897	61	-18	54	0	69	11	79	21	78	31	88	37	96	50	92	42	96	28	86	25	65	12	60	2
1898	64	-1	64	-9	71	12	77	16	81	32	90	40	96	45	90	46	90	38	86	24	68	13	56	1
1899	55	-6	57	-21	67	9	86	21	86	30	92	40	94	45	95	39	94	32	92	22	66	22	63	-2
1900	54	-5	65	-10	57	-4	78	20	89	25	90	44	95	44	94	49	89	41	86	30	69	6	55	11
1901	53	-4	40	0	69	-1	82	22	82	33	91	38	95	50	94	47	86	34	79	26	67	18	64	-11
1902	47	2	59	-9	69	9	83	24	97	29	89	39	93	46	88	40	85	32	77	27	72	24	60	-5
1903	60	-8	63	-9	76	21	74	19	89	27	88	41	94	42	92	43	89	32	79	26	71	9	49	-2
1904	60	-21	57	-10	74	13	72	12	88	33	88	44	92	46	90	42	89	31	83	19	68	15	63	-1
1905	59	-8	43	-12	79	10	77	23	82	31	89	38	92	50	90	46	87	36	80	23	61	16	52	13
1906	72	6	65	-14	61	-5	80	21	86	29	92	47	88	46	91	48	90	44	74	22	72	23	58	6
1907	67	-14	50	-5	82	12	78	15	81	29	89	40	88	40	90	43	88	34	82	22	55	18	56	9
1908	51	4	56	-3	75	21	80	24	89	30	91	36	92	46	95	43	95	28	84	24	68	17	59	7
1909	66	-11	60	-2	60	12	81	13	84	31	89	42	89	45	89	41	90	30	81	22	72	21	66	-6
1910	45	-1	48	-12	84	18	81	23	82	25	90	35	94	44	94	38	91	34	85	24	66	14	49	0
1911	56	-11	62	9	67	4	77	16	92	28	94	46	101	43	97	41	87	37	75	22	65	10	61	7
1912	44	-24	55	-16	68	6	78	23	86	36	88	31	90	51	89	41	93	30	82	26	68	18	58	8
Extremes	72	-24	65	-21	84	-5	92	12	97	25	98	31	101	40	99	37	98	28	92	19	72	6	68	-11

METEOROLOGY—TABLE XI. Concluded

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-FIVE YEARS FOR THE STATE

Date	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	68	—15	69	—10	77	—6	92	19	91	23	102	34	97	42	102	35	92	26	80	22	81	17	63	1
1889	61	1	70	—14	82	10	88	15	96	26	92	38	98	47	100	40	99	28	83	17	77	9	73	10
1890	75	1	73	1	69	—4	86	20	92	28	101	39	101	43	103	40	92	33	85	29	77	17	65	3
1891	65	8	80	—2	74	—5	95	15	93	25	98	40	95	41	101	39	99	36	93	20	76	0	66	9
1892	61	—25	74	1	80	6	90	14	99	28	101	47	103	40	99	45	96	34	89	20	76	8	70	—12
1893	63	—24	68	—14	87	—8	93	20	94	23	102	40	101	42	101	37	100	24	95	15	76	1	72	—5
1894	66	—16	76	—15	91	3	97	16	98	31	102	29	106	36	104	36	103	27	90	15	79	4	70	—27
1895	62	—19	70	—24	86	—7	90	16	102	19	105	29	106	34	103	31	105	25	84	8	85	5	79	—13
1896	70	—4	78	—18	73	—7	103	15	99	36	98	23	102	39	102	35	100	25	85	17	79	7	67	—15
1897	71	—27	72	—9	82	5	92	11	91	25	102	31	113	44	101	38	105	25	97	20	76	8	71	—7
1898	71	—18	72	—20	84	5	87	10	92	29	99	39	106	38	100	40	102	38	96	20	76	2	67	—18
1899	66	—15	67	—39	76	0	94	6	96	28	102	36	106	41	104	39	107	26	94	20	79	18	69	—7
1900	67	—26	80	—20	70	—9	87	15	97	20	96	38	103	38	103	40	100	33	93	23	80	..	65	—2
1901	67	—10	60	—20	84	—8	91	18	90	26	103	30	109	48	101	42	98	29	88	20	79	10	73	—19
1902	63	—11	66	—17	82	—4	90	17	98	24	98	33	100	43	97	37	94	24	88	21	87	17	63	—11
1903	73	—13	69	—20	85	11	88	10	93	22	95	35	104	42	101	38	98	26	93	15	88	2	57	—11
1904	70	—30	75	—18	86	—1	81	7	95	27	98	37	99	41	97	38	99	23	92	15	73	0	69	—16
1905	65	—17	54	—20	85	—5	89	12	93	26	99	34	100	44	96	41	95	30	89	20	71	10	58	2
1906	79	—14	72	—23	74	—12	91	18	94	24	100	34	98	43	101	43	98	36	91	18	82	14	68	—15
1907	75	—23	66	—19	96	—2	86	10	89	24	96	36	98	37	96	40	93	29	88	19	71	11	69	2
1908	59	—8	66	—22	85	12	91	16	96	25	100	33	102	42	104	37	100	23	90	15	77	5	68	—2
1909	74	—17	70	—17	70	6	90	13	91	24	96	36	97	40	96	35	94	25	96	16	80	15	75	—20
1910	62	—24	68	—25	90	12	88	19	88	21	97	33	98	42	98	36	93	34	94	18	78	11	63	—10
1911	68	—19	76	—2	81	1	86	9	101	25	101	40	107	41	104	39	97	33	88	20	79	8	79	—3
1912	58	—37	68	—25	80	—3	89	15	93	31	93	28	101	42	95	40	99	29	93	23	82	8	74	—5
Extremes	79	—37	80	—39	96	—12	103	6	102	19	105	28	113	34	104	31	107	23	97	8	88	0	79	—27

TABLE XII: MONTHLY RAINFALL AT DISTRICT TEST-FARMS.

Rainfall—inches.

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
							Strongsville							
1897	.91	1.62	3.29	3.88	5.99	1.88	5.56	3.25	1.13	.87	7.02	1.92	37.32	1897
1898	5.47	3.75	4.82	2.37	3.43	5.60	4.25	5.69	2.72	5.59	3.25	7.39	54.33	1898
1899	4.35	2.32	5.25	3.11	5.58	2.10	5.75	.61	3.14	2.86	1.55	6.36	42.98	1899
1900	3.22	5.53	3.01	2.22	1.85	1.38	4.73	2.49	3.56	2.22	4.91	1.94	37.04	1900
1901	2.73	2.20	4.35	4.76	5.14	3.32	3.15	7.46	5.51	.47	2.51	5.34	46.94	1901
1902	1.17	1.40	2.64	2.91	4.29	9.34	7.39	4.52	5.68	2.73	2.35	3.34	47.66	1902
1903	2.37	2.97	3.18	6.68	1.45	3.78	6.49	3.72	1.88	3.09	2.70	2.62	45.93	1903
1904	6.51	3.59	4.68	3.47	6.07	1.45	5.80	3.48	2.73	1.20	.50	3.87	43.35	1904
1905	2.48	2.73	3.24	3.97	4.38	2.18	5.04	4.11	3.50	2.95	2.92	1.66	39.16	1905
1906	2.03	2.06	....	1.98	1.01	4.67	2.72	4.30	6.70	....	4.77	5.12	.....	1906
1907	5.21	1.20	....	....	....	....	....	....	....	....	....	....	.....	1907
1908	....	....	....	....	2.82	2.78	3.70	3.10	1.00	1.60	1.08	1.90	.....	1908
1909	2.48	2.56	....	3.49	4.13	3.20	4.40	3.60	2.71	2.60	2.80	1.30	.....	1909
1910	4.80	2.21	1.10	....	3.05	2.50	1.00	1.37	4.85	3.90	3.98	2.99	.....	1910
1911	....	1.16	1.85	3.03	1.95	1.80	.80	3.28	5.33	3.85	....	1.51	.....	1911
1912	1.38	1.49	2.91	5.12	3.62	1.80	6.88	4.74	4.34	2.40	.20	1.89	36.77	1912
Av....	3.22	2.45	3.36	3.91	3.65	3.18	4.51	4.05	3.65	2.59	2.90	3.28	.....	....

TABLE XII: MONTHLY RAINFALL AT DISTRICT TEST-FARMS—Continued.

Rainfall—inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
							Germantown							
1905	....	....	....	3.45	7.70	3.00	3.80	7.90	3.56	4 10	2.24	2.28	.....	1905
1906	2.92	1.07	6.98	1.88	1.34	2.88	6.24	7.46	2.30	1.65	3.80	4.32	42.79	1906
1907	7.22	.32	6.25	2.26	3.20	3.65	4.10	1.93	5.64	2.92	3.25	3.22	43.96	1907
1908	2.11	6.33	4.24	4.53	4.47	1.42	3.86	1.36	.35	.27	1.70	1.31	31.95	1908
1909	3.41	7.67	2.07	5.58	6.98	5.93	4.50	3.34	.89	3.13	1.95	4.00	49.45	1909
1910	3.00	4.25	.10	1.87	5.08	1.58	3.95	1.11	3.96	7.60	.96	2.85	36.41	1910
1911	5.00	1.46	3.00	6.01	1.36	2.67	1.78	4.56	5.16	4.48	3.06	3.81	42.35	1911
1912	3.23	1.68	4.29	6.51	3.49	2.24	3.78	9.05	2.50	2.79	.72	3.30	43.58	1912
Av.....	3.84	3.28	3.84	4.01	4.20	2.92	4.00	4.59	3.05	3.37	2.21	3.14	41.50	....
							Carpenter							
1903	....	....	....	3.75	5.09	5.07	4.23	1.02	1.02	2.60	2.73	3.28	.....	1903
1904	3.74	2.89	5.07	3.03	2.69	3.16	3.79	2.71	2.08	1.10	.18	3.40	33.84	1904
1905	1.02	1.35	4.07	2.70	7.02	5.11	3.77	4.11	1.02	5.20	2.45	3.51	41.33	1905
1906	3.58	1.85	3.82	1.43	1.40	6.39	1.40	2.92	3.24	2.58	3.50	3.50	35.61	1906
1907	8.94	2.28	6.13	3.57	3.47	4.49	4.84	4.10	2.94	2.38	2.14	1.72	47.00	1907
1908	1.37	4.31	7.80	5.15	4.36	2.92	3.74	3.50	.48	.85	1.37	2.13	37.98	1908
1909	3.05	5.72	2.77	4.10	4.29	7.63	4.18	2.18	.86	2.12	.90	2.05	39.85	1909
1910	6.40	4.70	.20	3.23	2.91	2.35	3.40	1.74	.89	1.68	1.42	2.80	31.82	1910
1911	5.58	3.06	2.26	3.90	2.06	6.14	1.19	4.69	5.18	3.68	2.20	4.01	43.95	1911
1912	1.48	2.44	3.39	4.04	2.90	2.92	5.46	2.56	2.51	1.80	.38	2.09	.....	1912
Av.....	3.90	3.18	3.95	3.49	3.68	4.62	3.60	2.95	2.03	2.39	1.73	2.86	38.92	....

THE MAINTENANCE OF FERTILITY
THE STRONGSVILLE EXPERIMENTS

OHIO

Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., APRIL, 1918.

BULLETIN 260

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[1] In cooperation with Bureau of Plant Industry, U. S. Department of Agriculture.
[2] In cooperation with Boys' Industrial School. [3] In cooperation with Ohio State Reformatory.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 260 APRIL, 1913.

EXPERIMENTS WITH FERTILIZERS, MANURE, LIME AND FLOATS

MADE ON THE

NORTHEASTERN TEST FARM

OF THE

OHIO AGRICULTURAL EXPERIMENT STATION

AT STRONGSVILLE, CUYAHOGA COUNTY, OHIO

The administrative offices and scientific laboratories of the Ohio Agricultural Experiment Station are located on a farm near Wooster, in Wayne county, but the Station operates eight other farms, located in as many different counties in the state, on which experiments are being conducted with just as much care as is given to those on the central farm; the object of this distribution of work being to bring under investigation the principal soil formations of the state and to study the effect on farm crops of such climatic variations as occur within the state.

The first to be located of these outlying farms was the one in Strongsville Township, Cuyahoga county, about 14 miles southwest of Cleveland, 4 miles south of Berea and 36 miles north of the Central Station. As originally established, this farm consisted of two tracts, one of 60 acres, belonging to M. C. Blake, and one of 40 acres, belonging to O. D. Pomeroy. These tracts were leased for a term of ten years and work was begun in the spring of 1895. Before the expiration of the lease 85 acres additional land was leased of Mr. Pomeroy and the leases on both tracts were extended for three years, at the end of which time the work on the Blake farm was discontinued and the Pomeroy tract of 125 acres was purchased by the Station.

Since the location of the experiment farm the Cleveland, Lorain & Wheeling Railway (B. & O. System) has built a line past the farm, locating a station (Strongsville) on the northwest corner; and the Cleveland & Southwestern Electric Railway has been built along the western boundary.

The soil of the Strongsville farm is a heavy, white clay, lying upon an argillaceous shale from which it has been largely derived, though modified by glacial action. The shale comes to the surface in places in low ridges in which the rock is found to be crumpled as by lateral pressure—an epitome of the movements which have taken place in mountain building. The farm lies about 12 miles from the lake and slopes gradually to the north. The topography and the color and markings of the surface shale suggest that the shale has been deposited as a mud in shallow water at a comparatively recent period, as measured by geologic time. The subsoil and underlying shales are so impervious to water that underdrainage is essential to profitable cultivation. The original forest growth was chiefly beech and elm, with sugar maples on the better drained portions.

The first experiments started on these farms were a 3-year rotation of potatoes, wheat and clover and a 3-year rotation of corn, wheat and clover on the Blake land, and a 5-year rotation of corn, oats, wheat, clover and timothy on the Pomeroy land.

The land for these experiments, except one section on the Pomeroy land, was underdrained at the beginning of the work with tile drains, laid 30 inches deep and 36 feet apart. We have discovered no reason for changing the depth of drainage, as the water soon disappears from the areas immediately over the drains, but they are too far apart for the best effect on this soil. This particular distance was adopted because the plots, into which the experiment fields are divided, are 16 feet wide and are separated by paths two feet wide, thus making the distance 18 feet between centers, and tile drains were laid under alternate paths, thus giving a drain on one side or the other of every plot. It would have been much better to put a drain under every path, but insufficiency of funds led to the trial, as a compromise, of the system mentioned.

At the first plowing, and subsequently at intervals of 5 to 10 years, the plots have been plowed lengthwise and separately, thus leaving deadfurrows between plots; at other times the plowing has been across plots.

The fertilizers have been applied for all crops alike with the same implement—the ordinary grain and fertilizer drill—the application being made a few days before planting or sowing the crop. By this method of application such crops as corn and potatoes are encouraged to spread their roots over the whole surface, instead of concentrating them around a limited area, and thus they are better prepared to obtain moisture in times of drouth. Moreover, the results of these and other experiments of this Station have shown that the crop immediately fertilized never consumes all the plant

nutrients given, but a considerable portion becomes available only to subsequent crops and it is highly desirable that this residue should be so distributed that these crops, which are small grains and grasses in a balanced rotation, should find it so located as to be uniformly accessible. A further objection to fertilizing in the hill or drill is that the germination of the seed is injuriously affected when fertilizing materials are placed in contact with the seed.

THE POTATOES-WHEAT-CLOVER-ROTATION

This rotation was planned as a duplicate of the similar rotation at the main Station, three tracts of land being occupied by the experiment, in order that each crop might be grown every season, the plots being arranged and numbered as shown in Diagram I, and the plan of fertilizing as given in Table I.

For 7 years, from 1895 to 1901, inclusive, potatoes were planted in this experiment, but the soil selected proved to be so unsuited to this crop that the attempt to grow it was abandoned, and after growing and plowing under a crop of soybeans on each of the three tracts the plan of fertilizing was rearranged, and corn was substituted for potatoes.

The clover crop also failed during the first years of this test, owing to the acidity of the soil; but wheat was more successfully grown, and Table II shows the average yield and increase in the wheat crop for the 8 years, 1897-1904, inclusive.

Table II shows that the carriers of phosphorus in every case doubled, or more than doubled the yield of wheat in this experiment, while the carriers of potassium and nitrogen produced practically no effect when used alone and a very small effect when used in combination with each other only but in the absence of phosphorus. When either nitrate of soda or muriate of potash was added to the acid phosphate a considerable increase was produced over that given by the phosphate alone, the additional increase being much greater than that produced by any one of the three carriers when used alone. When all three carriers were used in combination, however, the increase was no greater than that produced by acid phosphate and nitrate of soda without the potash on Plot 6. The larger increase found on Plot 14 is apparently due to the larger application of acid phosphate to the preceding potato crop.

The nitrogen and phosphorus were given in wheat bran on Plot 20, 1896 to 1898, but the increase was less than that obtained from acid phosphate alone, a result which was also observed in the similar experiments at Wooster, and consequently the bran was replaced in 1899 by acid phosphate and nitrate of soda, the ration of nitrogen on this

plot and on Plots 21, 23 and 24 being reduced by one-half, in order that the relative effect of the different carriers of nitrogen might not be obscured by such large applications that even the less effective carriers would provide all that the crop could use. The outcome was that linseed oilmeal and dried blood have shown nearly equal effectiveness with nitrate of soda, as nitrogen carriers for wheat, but the plot receiving sulphate of ammonia shows a lower rate of yield—a difference, however, which has disappeared when lime has been added.

TABLE I: Plan of fertilizing in potatoes-wheat-clover rotation

Pl't	Fertilizing materials, pounds per acre									Fertilizing elements, pounds per acre		
	On potatoes			On wheat				Total fertilizers for one rotation				
	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Dried blood	Nitrate of soda	Quantity	Cost	Phosphorus	Potassium	Nitrogen
1	...	...	...	...	...	...	...	...	....	..	..	..
2	160	...	...	160	...	...	...	320	$ 2.40	20	..	..
3	...	100	...	...	100	...	...	200	5.00	..	83	..
4	...	...	...	...	...	...	...	...	....	..	..	..
5	...	...	80	...	...	50	120	250	6.00	..	..	38
6	160	...	80	160	...	50	120	570	8.40	20	..	38
7	...	...	...	...	...	...	...	...	....	..	..	..
8	160	100	...	160	100	...	...	520	7.40	20	83	..
9	...	100	80	...	100	50	120	450	11.00	..	83	38
10	...	...	...	...	...	...	...	...	...	..	..	..
11	160	100	80	160	100	50	120	770	13.40	20	83	38
12	160	100	160	160	100	50	200	930	17.30	20	83	62
13	...	...	...	...	...	...	...	...	...	..	..	..
14	320	200	160	160	100	50	120	1,110	19.10	30	125	51
15	480	300	320	...	...	...	...	1,110	19.10	30	125	51
16	...	...	...	...	...	...	...	...	...	..	..	..
17	...	...	...	A	...	...	...	8,000	...	..	..	..
18	...	...	...	B	...	...	...	16,000	...	..	..	..
19	...	...	...	...	...	...	...	...	...	..	..	..
20	160	100	80	160	100	25	60	685	11.40	20	83	25⅓
21	145	95	C	145	95	...	C	940	11.40	20	83	25⅓
22	...	...	...	...	...	...	..	...	...	..	..	..
23	150	100	D	150	100	100	...	700	11.40	20	83	25⅓
24	160	100	E	160	100	25	F	650	11.40	20	83	25⅓
25	...	...	...	...	...	...	...	...	...	..	..	..
26	G	100	55	G	100	20	120	615	13.40	20	83	38
27	H	100	80	H	100	50	120	730	13.40	20	83	38
28	...	...	...	...	...	...	...	...	...	..	..	..
29	I	100	80	I	100	50	120	710	13.40	20	83	38
30	K	...	...	...	...	...	...	16,000	...	..	..	..
31	...	...	...	...	...	...	...	...	...	..	..	..
32	...	...	...	L	...	...	...	32,000	...	..	..	..
33	M	...	...	M	...	...	...	...	...	20	83	25⅓
34	...	...	...	...	...	...	...	...	...	..	..	..
35	160	50	80	160	50	50	120	670	10.90	20	41½	38
36	160	25	80	160	50	25	120	620	9.65	20	20¾	38
37	...	...	...	...	...	.	...	...	...	..	..	..
38	...	...	...	...	...	...	...	...	...	..	..	..

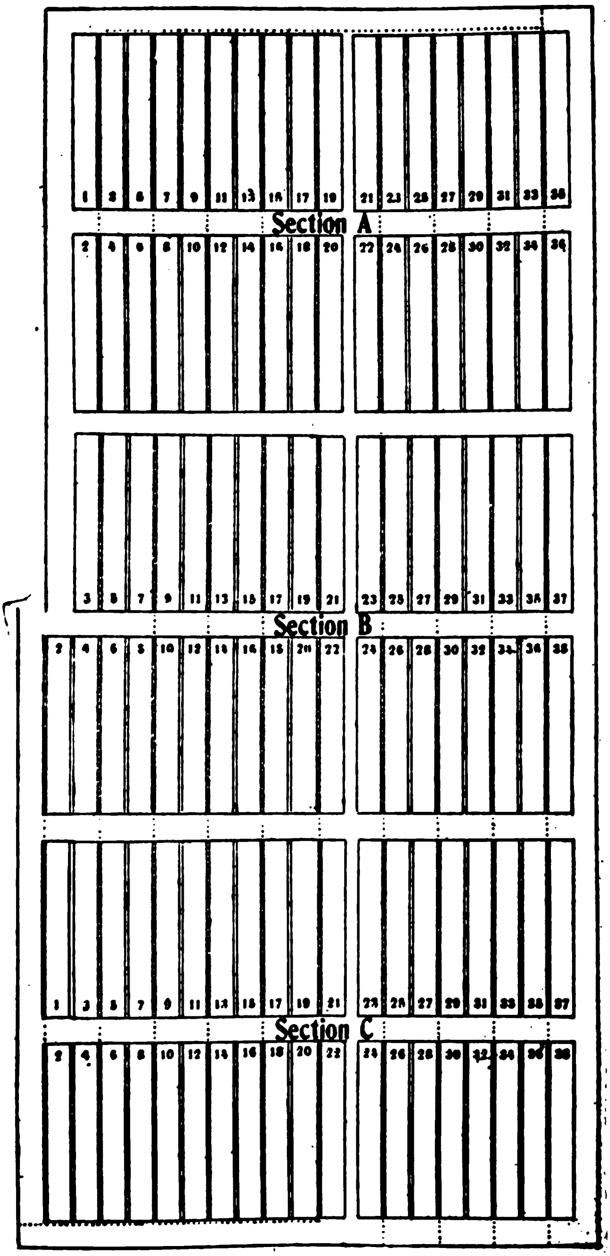
A—Barnyard manure, 4 tons. B—Barnyard manure, 8 tons. C—Linseed oilmeal, 230 lbs. D—Dried blood, 100 lbs. E—Sulphate of ammonia, 60 lbs. F—Sulphate of ammonia, 45 lbs. G—Raw bone meal, 110 lbs. H—Dissolved boneblack, 140 lbs. I—Basic slag, 130 lbs. K—Barnyard manure, 8 tons. L—Barnyard manure, 16 tons. M—A mixture of acid phosphate, muriate of potash and tankage, made up to analyze 3½ percent "ammonia," 13 percent "phosphoric acid" and 2½ percent "potash," prior to 1899. Since that date same materials, mixed to correspond in composition with dressings on Plots 20, 21, 23 and 24.

*For the details of this experiment for the earlier years, see Bulletin 110, pp. 18-25, and Bulletin 125, pp. 121-132

ARRANGEMENT OF PLOTS IN POTATOES-WHEAT-CLOVER ROTATION

DIAGRAM I

Plots one-twentieth acre.



The manure used in this test was chiefly horse manure, which had been in an open yard for several months before application, under the conditions which are found in the average barnyard. That such treatment is extremely wasteful is shown by the experiments reported in Bulletin 183 of this Station.

TABLE II. Wheat following potatoes in rotation, 8-year average yield, 1897-1904.

Plot No.	Treatment per acre on wheat[1]	Yield per acre		Increase per acre	
		Grain	Straw	Grain	Straw
		Bus.	Lbs.	Bus.	Lbs.
1	None	10.31	887	.....	.....
2	Acid phosphate, 160 lbs	18.84	1,738	10.08	1,028
3	Muriate of potash, 100 lbs	10.72	909	.81	73
4	None	8.76	710	.....	.....
5	Nitrate of soda, 160 lbs	9.60	766	.08	—19
6	Acid phosphate, 160 lbs.; nitrate of soda, 160 lbs	23.00	1,888	14.45	1,198
7	None	9.12	734	.....	.....
8	Acid phosphate, 160 lbs.; muriate of potash, 100 lbs	22.32	1,737	13.99	1,068
9	Muriate of potash, 100 lbs.; nitrate of soda, 160 lbs	10.69	854	2.07	148
10	None	8.12	649	.....	.....
11	Acid phos., 160 lbs.; mur. potash, 100 lbs.; nit. soda, 160 lbs	21.88	1,840	13.75	1,162
12	Acid phos., 160 lbs.; mur. potash, 100 lbs.; nit. soda, 240 lbs	21.80	1,842	13.98	1,232
13	None	7.63	650	.....	.....
14	Acid phos., 160 lbs.; mur. potash, 100 lbs.; nit. soda, 160 lbs.[2]	23.23	1,842	15.72	1,271
15	None[3]	19.93	1,586	12.13	937
16	None	7.21	532	.....	.....
17	Yard manure, 4 tons[4]	11.86	891	3.89	242
18	Yard manure, 8 tons[4]	15.01	1,283	7.38	706
19	None	8.13	648	.....	.....
20	Same elements as on Plot 11, but phos., and nit. in wheat bran[5]	16.21	1,283	8.15	660
21	Same elements as on Plot 20, but nit. in linseed oilmeal	20.23	1,535	12.15	899
22	None	8.48	668	.....	.....
23	Same elements as on Plot 20, but nit. in dried blood	19.75	1,471	11.71	848
24	Same elements as on Plot 20, but nit. in sulphate of ammonia	18.69	1,568	10.69	923
25	None	7.99	611	.....	.....
26	Same elements as on Plot 11, but phos. in raw bone meal	21.56	1,819	14.04	1,196
27	Same elements as on Plot 11, but phos. in dissolved boneblack	19.19	1,508	11.18	886
28	None	7.03	600	.....	.....
29	Same elements as on Plot 11, but phosphorus in basic slag	21.24	1,689	13.22	1,064
30	None (following yard manure, 16 tons, on potatoes)	11.66	1,029	4.53	427
31	None	8.04	647	.....	.....
32	Yard manure, 16 tons	18.73	1,574	11.49	970
33	Acid phos., 100 lbs.; 7-30 tankage, 100 lbs.; mur. potash, 10 lbs.	23.14	1,666	15.49	1,065
34	None	7.34	606	.....	.....
35	Acid phos. 160 lbs.; mur. potash, 50 lbs.; nit. soda, 160 lbs	20.41	1,712	13.16	1,157
36	Acid phos. 160 lbs., mur. potash, 25 lbs.; nit. soda, 160 lbs	21.46	1,738	13.84	1,091
37	None	6.86	509	.....	.....
38	None	7.90	688	.....	.....
	Average unfertilized yield	8.07	653		

[1]Except as otherwise noted the preceding potato crop received the same quantities of phosphorus and potassium and half the quantity of nitrogen given to the wheat. [2]Following 320 lbs acid phos.; 100 lbs. mur. potash, and 160 lbs. nitrate soda on potatoes. [3]Following 480 lbs acid phos.; 200 lbs mur. potash and 320 lbs. nitrate soda on potatoes. [4]No treatment on potatoes. [5]For the crops of 1900 and since, 80 lbs. nitrate of soda on Plot 20 and the equivalent of this amount on Plots 21, 23 and 24.

As between the different carriers of phosphorus there is apparently but little difference. As judged by other experiments the relatively high yield from raw bonemeal and low yield from dissolved bone black were most likely due to soil variation.

In Diagram II the average yield of these wheat crops is compared with the yield of the wheat crops grown during the same period in the duplicate experiment at the main station at Wooster, the treatment being identical on the plots of the same number. The diagram shows that with but few exceptions the "fertilized" lines follow the same general course, although the relative effect of the treatments has been much greater on the Strongsville soil, with its average unfertilized yield of 8 bushels per acre, than on that at Wooster, where the average unfertilized yield for this period amounted to 24.7 bushels.

AN EXPERIMENT WITH LIME

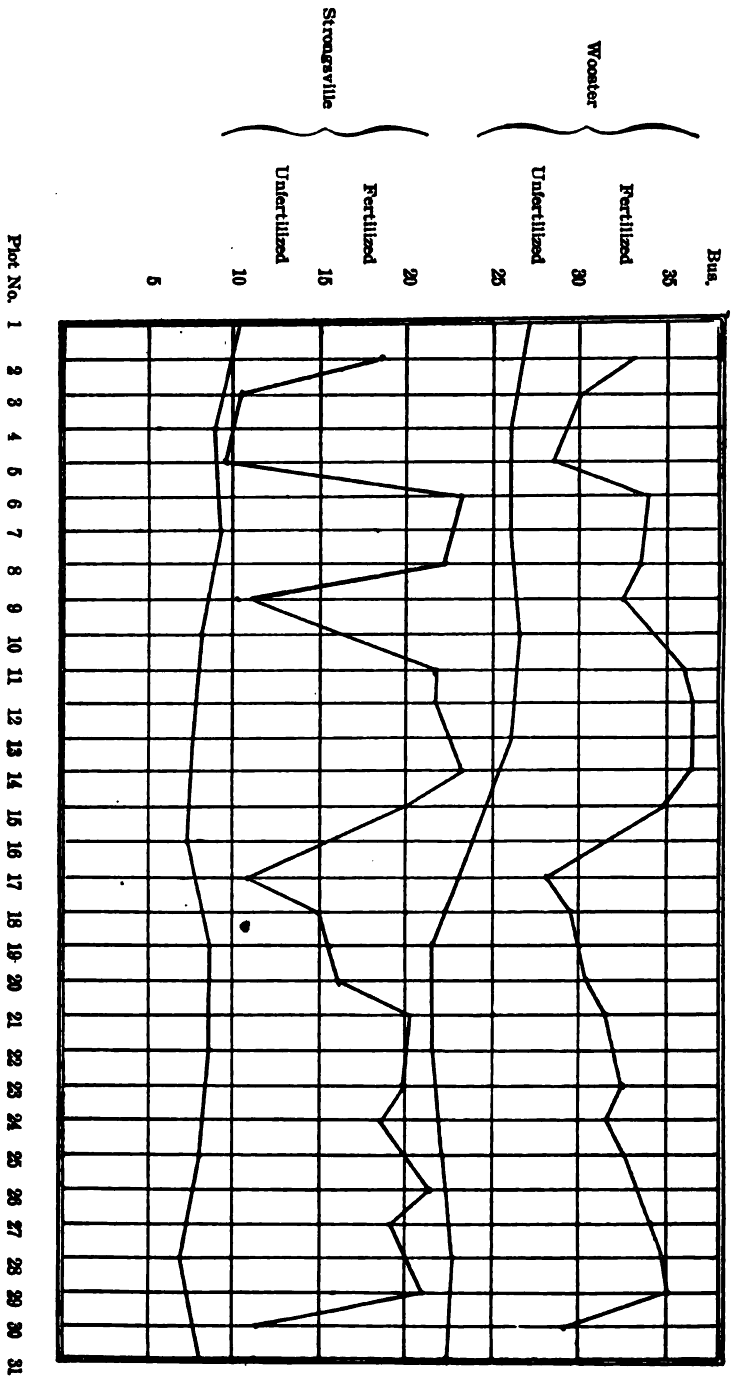
In rearranging this experiment, Plots 1 to 19 received in general the same fertilizers and manure that they had previously received, the differences in treatment being to substitute corn for potatoes in the cropping, to reduce the quantity of muriate of potash, and to increase the total application on Plot 15.

On Plots 19 to 38 a new experiment was started in the use of different carriers of lime. In this experiment all the fertilized plots except Nos. 33, 35 and 36 had received the same quantities of the fertilizing elements during the first period, but in different carriers. During the second period these plots were each given 160 pounds of acid phosphate, 80 pounds of muriate of potash and 160 pounds of nitrate of soda on corn and the same on wheat, the different lime carriers being used as shown in Table IV.

In Table III is given the results attained on Plots 1 to 19 during the second period, with the financial outcome, the value of the increase being computed on the basis of 40 cents per bushel for corn 80 cents for wheat, $3.00 per ton for corn stover, $2.00 for straw and $8.00 for hay.

Acid phosphate, when used alone, appears to have been less effective during this second period than during the first, and the same may be said of muriate of potash and nitrate of soda, while the combinations of the elements have been generally more effective, especially the large application on Plot 14. While this plot gives the largest total yield, the wheat crop reaching an average for the 4 years of more than 30 bushels per acre, the cost of the fertilizer reduces the net gain to a point below that realized on Plot 8, receiving only the cheaper mineral fertilizers, without nitrogen.

DIAGRAM II



YIELD OF WHEAT IN POTATOES-WHEAT-CLOVER ROTATION

TABLE III: Plan of treatment, average yield and increase and value of increase in corn-wheat-clover rotation. Fertilizer test. Second period, 1905 to 1909 inclusive.

Plot	Fertilizer per acre for one rotation			Yield per acre					Increase per acre					For one rotation			Plot
				Corn 5-year rotation		Wheat 4-year average		Hay 4-year av.	Corn 5-year average		Wheat 4-year average		Hay 4-year av.	Value of increase	Cost of fertilizer	Net gain or loss (—)	
	Acid phos-phate	Muriate potash	Nitrate soda	Grain	Stover	Grain	Straw		Grain	Stover	Grain	Straw					
No.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Lbs.	$	$	$	No.
1	...	.	...	.....	.....	6.85	1,184	.....	....	...	.....	.....	.....	.....	.....	.....	1
2	320	..	...	28.89	1,623	12.85	1,659	3,405	5.98	187	2.87	465	485	7.37	2.60	4.77	2
3	...	80	...	24.26	1,804	7.31	971	2,725	—5.25	—208	—.56	—220	—242	—4.05	2.00	—6.05	3
4	...	..	...	27.75	1,654	9.98	1,194	2,920	.....	...	.....	.....	.....	.....	.....	.....	4
5	...	..	320	30.57	2,012	9.75	1,265	2,805	1.10	—59	.86	65	—113	—0.65	9.60	—8.95	5
6	320	..	320	43.00	2,326	26.19	2,744	4,160	14.63	633	15.77	1,573	1,165	25.65	12.20	13.45	6
7	...	..	...	30.44	2,129	9.91	1,205	2,870	.....	...	.....	.....	.....	.....	.....	.....	7
8	320	80	...	42.60	2,434	23.79	2,432	3,835	13.60	702	12.92	1 283	765	21.17	4.60	16.57	8
9	...	80	320	31.78	2,100	15.39	1,451	3,410	2.14	156	4.75	268	460	7.00	11.60	—4.60	9
10	...	...	...	29.62	1,771	11.31	1,126	3,145	.....	...	.....	.....	.....	.....	.....	.....	10
11	320	80	320	41.56	2,362	23.58	2,415	3,690	12.72	416	12.21	1,254	660	19.39	14.20	5.19	11
12	320	80	480	40.60	2,160	27.54	2,797	3,690	11.81	451	15.72	1,622	607	22.02	19.00	3.03	12
13	...	..	...	28.04	1,854	12.11	1,139	3,110	.....	...	.....	.....	.....	.....	.....	.....	13
14	480	80	320	43.44	2,254	30.83	3,070	4,185	15.48	608	18.50	1,847	1,163	28.40	14.90	13.50	14
15	640	80	480	41.29	2,478	30.71	3,137	4,110	16.55	683	18.89	2,009	970	28.64	21.60	7.04	15
16	...	..	...	27.14	1,584	12.83	1,272	2,960	.....	...	.....	.....	.....	.....	.....	.....	16
17	Yard manure, 4 tons.......			35.36	2,060	15.19	1,714	3,460	7.93	324	3.65	596	290	8.33	?	?	17
18	Yard manure, 8 tons.......			39.60	2,136	19.19	1,989	4,070	11.47	514	5.11	578	958	13.86	?	?	18
19	...	..	...	27.13	1,677	11.25	1,107	3,200	.....	...	.....	.....	.....	.....	.....	.....	19
	Average unfertilized yield..			28.35	1,778	10.61	1,175	3,034									

[1]Computing corn at 40 cents per bushel, wheat at 80 cents, stover at $3.00 per ton, straw at $2.00 and hay at $8.00.

Table IV gives the outcome of the lime test in this experiment. In this part of the experiment the fertilized plots between Nos. 19 and 38 had received uniform applications of the three elements, nitrogen, phosphorus and potassium, but in different carriers. In rearranging the experiment these plots were given uniform quantities of nitrate of soda, acid phosphate and muriate of potash, divided equally between the corn and wheat, as on Plot 11, and lime, ground limestone and gypsum were added, as shown in the table.

Comparing Plot 20 with Plot 11 (Table III) it will be observed that the net gain on the two plots is practically the same, after deducting the additional cost due to the limestone; while on Plot 27, receiving twice the quantity of limestone given to Plot 20, the net gain is $1.72 greater than that on Plot 11.

Carbonate of lime contains about 56 percent as much calcium as quicklime. As quicklime slakes to a finer powder than can be obtained by grinding, it is assumed that one ton of quicklime and two tons of finely ground limestone will have approximately the same value in neutralizing acidity. Apparently this comparative value has not been attained in this test, but unfortunately the plots dressed with limestone in both quantities were plots which had shown an abnormally low yield during the first period of the test.

Comparing magnesian with non-magnesian lime, that is Plot 21 with Plot 23, and Plot 29 with Plot 33, it appears that the magnesian lime has in both cases produced the larger increase.

Comparing hydrated lime with quicklime it will be seen that the effect of the hydrated lime has been decidedly smaller than that of the quicklime—an outcome in harmony with the fact that in hydration, or slaking, lime takes up about one-third its weight of water. If the cost of hydrated lime were proportioned to its content of calcium it should be rated at about $5.00 per ton as laid on the field, instead of $6.50, but even this difference in cost would not fully balance the difference in outcome. It is probable, however, that the percentage of calcium and magnesium combined correctly represents the actual value of a lime carrier for neutralizing soil acidity, and that the failures to conform to these calculated values of the lime carriers used in this experiment are chiefly due to soil irregularity.

Taking the different rates of application, it will be seen that the average net gain has been nearly as great, after this short period, from the application of one ton per acre as from that of half that quantity. However, the table has been computed on the assumption that the cost of applying half a ton per acre is just half that of a

TABLE IV: Plan of treatment, average yield and increase and value of increase in corn-wheat-clover rotation. Lime test. Second period, 1905 to 1909 inclusive

Plot	Treatment	Yield per acre: Corn 5-yr. average: Grain	Yield per acre: Corn 5-yr. average: Stover	Yield per acre: Wheat 4-yr. average: Grain	Yield per acre: Wheat 4-yr. average: Straw	Yield per acre: Hay 4-year av.	Increase per acre: Corn 5-yr. average: Grain	Increase per acre: Corn 5-yr. average: Stover	Increase per acre: Wheat 4-yr. average: Grain	Increase per acre: Wheat 4-yr. average: Straw	Increase per acre: Hay 4-year av.	For one rotation: Value of increase[1]	For one rotation: Cost of treatment[2]	For one rotation: Net gain or loss(—)[3]	Plot
No.		Bus.	Lbs.	Bus.	Lbs.	Lbs.	Bus.	bs.	Bus.	Lbs.	Lbs.	$	$	$	No.
19	None	27.14	1,677	11.25	1,107	3,200	.....	...	.....	.....	.....	.....	.....	.....	19
20	Fertilizer: Ground limestone, 1,000 lbs	40.96	2,128	28.50	2,875	4,075	11.84	467	13.16	1,325	811	20.53	15.45	5.08	20
21	Fertilizer: Magnesian lime, 1,000 lbs	42.13	2,306	29.48	3,221	4,505	14.47	598	17.80	2,033	1,191	27.72	17.45	10.30	21
22	None	30.10	1,699	16.59	1,689	3,415	.....	...	.....	.....	.....	.....	.....	.....	22
23	Fertilizer: Non-magnesian lime, 1,000 lbs	43.97	2,450	28.71	2,852	4,685	15.78	712	16.61	1,584	1,258	27.28	17.45	9.83	23
24	Fertilizer: Hydrated lime, 1,000 lbs	41.28	2,138	30.11	3,167	4,155	12.70	540	14.47	1,579	938	22.80	17.45	5.35	24
25	None	28.72	1,771	12.52	1,349	3,540	.....	...	.....	.....	.....	.....	.....	.....	25
26	Fertilizer: Gypsum, 1,000 lbs	41.37	2,180	29.47	3,171	4,330	14.30	683	14.79	1,683	1,312	25.51	17.45	8.06	26
27	Fertilizer: Ground limestone, 2,000 lbs	42.10	2,280	28.29	2,775	4,435	13.44	515	15.15	1,402	986	24.61	16.70	6.91	27
28	None	25.56	1,396	13.75	1,387	2,820	.....	...	.....	.....	.....	.....	.....	.....	28
29	Fertilizer: Magnesian lime, 2,000 lbs	46.40	2,532	31.66	3,210	5,015	17.80	773	17.91	1 814	1,658	31.05	20.70	10.35	29
30	Manure, 8 tons: Lime, 1,000 lbs	36.44	2,006	21.18	2,338	4,365	10.33	533	7.41	8.81	1,423	17.43	? 3.25	14.18	30
31	None	28.55	1,753	14.37	1,420	3,265	.....	...	.....	.....	.....	.....	.....	.....	31
32	Manure, 16 tons: Lime, 2,000 lbs	39.31	2,320	20.75	2,632	4,755	12.65	769	6.96	1,104	1,692	19.65	? 6.50	13.15	32
33	Fertilizer: Non-magnesian lime, 2,000 lbs	48.04	2,624	30.89	3,121	4,395	19.43	933	17.10	1,798	1,090	29.01	20.70	8.31	33
34	None	27.22	1,625	13.81	1,598	3,185	.....	...	.....	.....	.....	.....	.....	.....	34
35	Fertilizer: Hydrated lime, 2,000 lbs	44.97	2,322	27.46	2,762	4,485	16.28	612	14.26	1,535	1,140	24.93	20.70	4.23	35
36	Fertilizer: Gypsum, 2,000 lbs	35.06	1,900	26.06	2,878	3,865	8.36	248	12.29	1,391	680	17.66	20.70	—3.04	36
37	None	21.98	1,327	12.62	1,130	.....	.....	...	.....	.....	.....	.....	.....	.....	37
38	None	19.66	1,251	13.72	1,376	.....	.....	...	.....	.....	.....	.....	.....	.....	38
	Average unfertilized yield	28.11	1,722	12.26	1,298	3,130									

[1]Computing corn at 40 cents per bushel, wheat at 80 cents, stover at $3.00 per ton, straw at $2.00 and hay at $8.00.
[2]Computing burned lime at $6.50, ground limestone at $2.50, gypsum, $6.50.
[3]Only a part of this net gain can be ascribed to the lime, as all the limed plots also received fertilizers equivalent to the application on Plot 11 (Table III).

whole ton, which is not always correct. If an exact computation were made on this point the larger application would in most cases be found the more profitable.

The computation has been made on the basis of $6.00 per ton at railway station for quicklime, hydrated lime or gypsum, and $2.00 per ton for ground limestone, with 50 cents per ton for hauling to the field and spreading—a computation which would not fit all cases.

Comparing Plot 18 (Table III) with Plot 30, both receiving the same dressing of 8 tons of manure per acre, it would seem that the lime applied to Plot 30 had fully repaid its cost.

Gypsum seems to have been used with profit on Plot 26 and at a loss in the larger quantity on Plot 36; but Plot 26 gave an abnormally high yield during the first 8 years of the experiment, whereas the yields of Plots 35 and 36 were nearly the same during this earlier period, that of Plot 36 being one bushel the larger. Judging from the effect of gypsum as compared with lime at the main station (see Circular 131, page 34) it seems probable that the increase shown on Plot 26 is in part due to other causes than the treatment.

It is unfortunate that it became necessary to discontinue this experiment after so short a period, as the rotation had only gone one year more than once around, thus not giving full opportunity to realize the full effect of the treatment on the crops following the clover. The land occupied by this test was in clover and timothy in 1912, and the effect of the previous treatment was very distinctly marked. It is probable that the "net gain," as shown in the table, does not represent half the total benefit following the treatment.

While the Experiment Station was located at Columbus an experiment was begun in the use of fertilizers and manure on wheat grown continuously on the same land. After seven years the treatment was discontinued, but wheat was grown and the yield ascertained for three years longer, with the result that the average increase for these three years was nearly as great from the fertilizers, and greater from the manure, than during the first seven years.

A COMPARISON OF FACTORY-MIXED WITH HOME-MIXED FERTILIZERS

The corn-wheat-clover rotation on the Blake land was planned as a comparison between factory-mixed and home-mixed fertilizers. The original plan of this experiment and the first year's results are given in Bulletin 93, and a further report is made in Bulletin 100. The experiment was begun in 1897 and was continued 8 years.

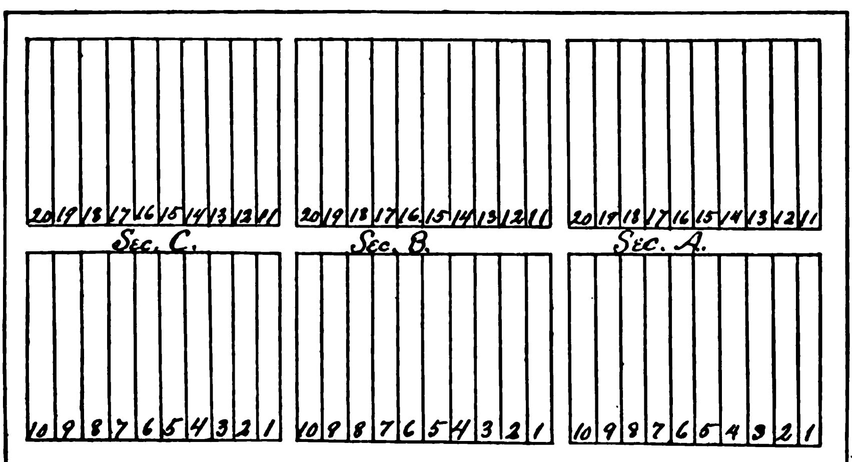
Four brands of fertilizers were purchased for the test from three prominent fertilizer establishments, the brands being designated A, B, C, D. The following percentage composition was claimed for these brands:

Percentage Composition

	Ammonia	Available phosphoric acid	Potash
Brand A	4	8	4
Brand B	2	10	1
Brand C	2	8	1
Brand D	1	6	1

These brands were duplicated by mixtures of tankage, acid phosphate and muriate of potash, the tankage having a composition of 7.8 percent ammonia and 13.49 percent phosphoric acid, as found by the Station chemists; the acid phosphate being the 14 percent grade. The quantity of these materials required to duplicate the several brands and their cost per ton in single sackful lots delivered at Wooster, together with the cost at Wooster of the proprietary brands used, are given in Table V; and the average results of the test for the 8 years are shown in Tables VI and VII. The arrangement of the plots is shown in Diagram III.

DIAGRAM III



The manufacturers of Brand A charged the Station $3.00 cash for a 200-pound sack, or at the rate of $30.00 per ton, and so on through the list, the Station paying the freight in each case. The bill rendered for the 200-pound sack of tankage was $1.70 in Cleveland, O., and the freight was 10 cents per hundred pounds, making

the total cost at the Station 95 cents per hundred pounds, or $19.00 per ton. The acid phosphate cost $1.00 per sack, or $10.00 per ton in Baltimore, Md., with 23 cents per hundred for freight, making the total cost per ton at the rate of $14.60. The muriate of potash cost 2 cents per pound in New York and the freight was 27 cents per hundred, bringing the cost up to $2.27 per hundred pounds.

The fertilizers were applied at the rate of 200 pounds per acre on corn and wheat; the manure at the rate of 8 tons per acre, on corn only. Factory Brand "A" was one for which it was claimed that the "wet mixing" process had been employed in its manufacture, whereas the home mixtures were, of course, "dry mixed."

TABLE V. Comparative composition of factory brands and their duplicates

Fertilizer	Quantity required per ton	Cost per ton	Pounds of constituents per ton				
			Ammonia	Phosphoric acid			Potash
				Available	Insoluble	Total	
	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Brand A.—Original	2,000	$30.00	80	160	40	200	80
Duplicate: Tankage	1,000	.....	80	80	60	140	..
Acid phosphate	700	......	..	98	14	112	..
Muriate potash	160	......	..	...	..	...	80
Total duplicate	1,860	$18.24	80	178	74	252	80
Brand B—Original	2,000	$25.00	40	200	20	220	20
Duplicate: Tankage	500	......	40	40	30	70	..
Acid phosphate	1,450	......	..	203	29	232	..
Muriate potash	50	......	..	...	..	...	25
Total duplicate	2,000	$16.47	40	243	59	302	25
Brand C.—Original	2,000	$20 00	40	160	40	200	20
Duplicate: Tankage	600	......	48	48	36	84	..
Acid phosphate	900	......	..	126	18	144	..
Muriate potash	50	......	..	...	..	...	25
Total duplicate	1,550	$13.41	48	174	54	228	25
Brand D.—Original	2,000	$17 50	20	120	20	140	20
Duplicate: Tankage	300	.....	24	24	18	42	..
Acid phosphate	700	.....	..	98	14	112	..
Muriate potash	50	......	..	...	..	...	25
Total duplicate	1,050	$ 9.10	24	122	32	154	25

The large increase produced by the bonemeal shows that phosphorus is the fertilizing element of chief importance for this soil; but that nitrogen and potassium also have a place, when associated with phosphorus, is shown by the experiment previously reported. The superior effect of the steamed bonemeal is presumably due in

part to its finer condition, making it more quickly available. The "phosphated" manure was manure which had been dusted with acid phosphate a short time before application, the phosphate being applied at the rate of 40 pounds per ton of manure, the cost of the treatment being $2.34 and the net gain, over the produce of the untreated manure, $4.06.

TABLE VI. Average yield per acre in comparison of factory mixed with home-mixed fertilizers

Plot	Fertilizer	Average yield per acre				
		Corn—8 years		Wheat—6 years		Hay 4-years
		Grain	Stover	Grain	Straw	
No.		Bus.	Lbs.	Bus.	Lbs.	Lbs.
1	None	18.45	1,238	5.20	368	1,805
2	Brand A	27.48	1,470	14.61	1,243	2,480
3	Duplicate A	27.11	1,446	16.34	1,248	2,715
4	None	22.27	1,333	4.34	397	1,805
5	Brand B	27.60	1,390	15.21	1,209	2,335
6	Duplicate B	32.66	1,661	18.23	1,311	2,570
7	None	21.52	1,316	3.48	285	1,420
8	Brand C	25.65	1,350	10.63	853	1,815
9	Duplicate C	24.18	1,447	12.08	999	1,740
10	None	18.75	1,264	3.77	347	1,230
11	None	21.20	1,267	5.23	443	2,105
12	Brand D	27.63	1,494	13.50	1,130	2,380
13	Duplicate D	27.21	1,525	13.59	1,137	2,310
14	None	23.33	1,332	4.61	451	1,880
15	Raw bonemeal	30.14	1,523	18.01	1,508	3,050
16	Steamed bonemeal	32.93	1,722	19.90	1,536	2,900
17	None	20.87	1,269	5.23	393	1,460
18	Yard manure	34.80	1,866	9.57	790	1,803
19	Phosphated manure	36.57	1,908	12.87	1,129	1,892
20	None	20.92	1,304	4.63	389	1,340

Plots 1-20 acre.

TABLE VII. Average increase per acre in comparison of factory-mixed with home-mixed fertilizers, value of increase, cost of fertilizer and net gain for one rotation

Plot	Fertilizer and formula	Average increase per acre					Value of increase	Cost of fertilizer	Net gain
		Corn		Wheat		Clover hay			
		Grain	Stover	Grain	Straw				
No.		Bus.	Lbs.	Bus.	Lbs.	Lbs.	$	$	$
2	Brand A, 4-8-4	7.76	200	9.69	865	675	14.72	6.00	8.72
3	Duplicate A, 4-8-4	6.10	145	11.71	861	910	16.52	3.65	12.87
5	Brand B, 2-10-1	5.58	64	11.16	849	658	14.74	5.00	9.74
6	Duplicate B, 2-10-1	10.89	340	14.46	988	1,021	21.50	3.30	18.20
8	Brand C, 2-8-1	5.05	51	7.05	548	458	10.11	4.00	6.11
9	Duplicate C, 2-8-1	4.51	165	8.40	669	447	11.23	2.70	8.53
12	Brand D, 1-6-1	5.72	205	8.47	684	350	11,45	3.50	7.95
13	Duplicate, D, 1-6-1	4.59	215	8.77	689	355	11.28	1.82	9.46
15	Raw bonemeal	7.64	212	13.19	1,076	1,309	20.24	2.80	17.44
16	Steamed bonemeal	11.24	432	14.89	1,123	1,300	23.38	2.80	20.58
18	Yard manure	13.90	584	4.54	397	383	12.00	....	?
19	Phosphated manure	15.67	616	8.04	738	511	16.40	2.34	?

The question whether there is any advantage in factory-mixing over home-mixing seemed to be so conclusively settled in favor of home-mixing that this experiment was discontinued in 1904.

THE 5-YEAR ROTATION

This rotation of corn, oats, wheat, clover and timothy is located on the Pomeroy land, in a tract lying on the north side of the road leading west from the south end of Strongsville village, the Blake land lying on the opposite side of the road. This part of the Pomeroy land is nearly level east and west, but slopes gently to the north. The experiment is laid out as is shown in Diagram IV, and the fertilizers are distributed as shown in Diagram V. Sections A, B, C and D were drained in 1905 with tile drains laid 30 inches deep under alternate plot divisions, thus spacing the drains 36 feet apart. Section E was not drained until 1912.

A partial report on this experiment was made in Bulletin 182, and the statistics of production, up to 1906, were given in Bulletin 184. These statistics will be continued in an appendix to the present report, in the form of 5-year averages.

In Table VIII is given a general summary of the results of this experiment by 5-year periods, and for the 17 years ending with 1911. The table shows that in every case there was a greater total increase from fertilizers carrying phosphorus during the second period than during the first. During the third period the total yield continued larger than during the first in the average, when the fertilizers contained phosphorus, but there were some exceptions; while in nearly every case the increase was smaller during the third period than during the second, the exceptions being Plots 3, 5, 8, 9 and 35. The differences on Plots 3 and 35 are so small as to be quite within the limits of error, but those on Plots 5, 8 and 9 would seem to indicate a relatively greater effectiveness for nitrogen and potassium during the later period. The manured plots all show a greater increase during the second period than during the first, and greater during the third period than during the second. While the increase from the fertilizers has been smaller during the third period than during the second, the unfertilized yield and the total yield of crops have been much greater, as shown by Table IX.

Table IX (page 424) shows that the total yields, both fertilized and unfertilized, have been much greater during the third period than during either of the preceding periods in all the crops except oats, but the rate of gain has been smaller than during the second period in all the crops except timothy.

A probable explanation of this outcome lies in the fact that, beginning in 1901, the experiment was modified by applying a dressing of lime to the south half of each section as it came under corn, the lime being applied at the rate of one ton of quicklime or two tons of ground limestone per acre, and spread over all the land, fertilized and unfertilized alike.

DIAGRAM IV. ARRANGEMENT OF PLOTS IN 5-YEAR ROTATION AT STRONGSVILLE

Plots one-tenth acre

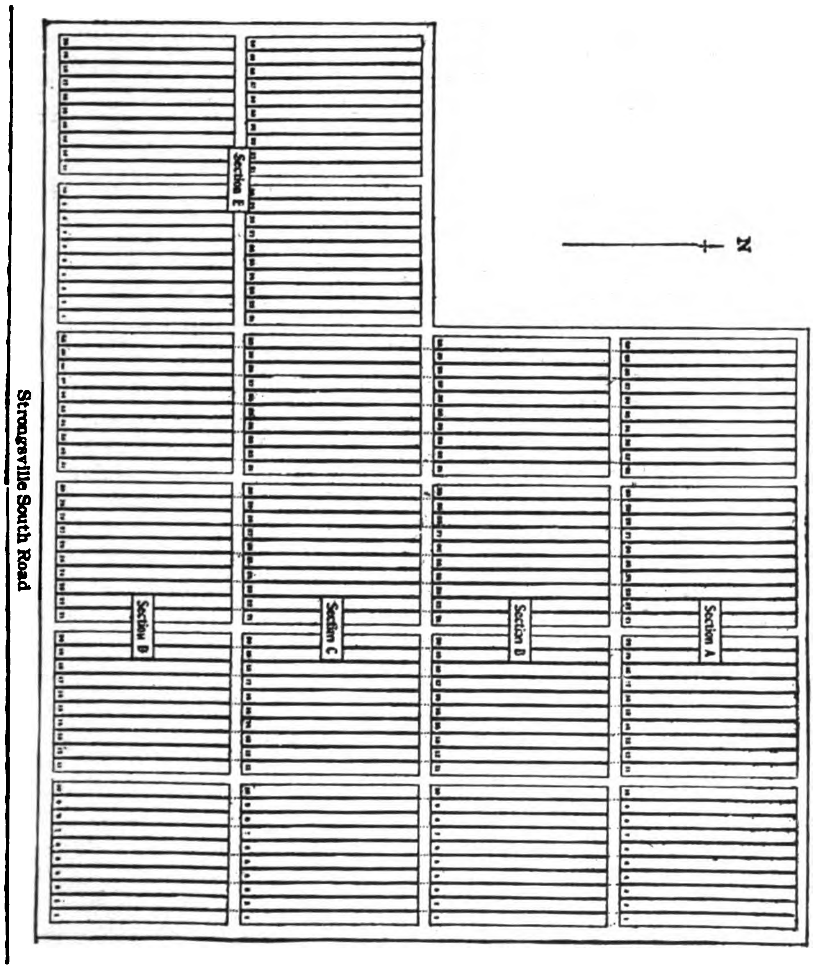


DIAGRAM V: PLAN OF FERTILIZING IN 5-YEAR ROTATION

Plots one-tenth acre Fertilizing materials in pounds per acre

Plot No.	On corn			On oats			On wheat			
	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of soda	Dried blood	Nitrate of soda
Roadway										
1	....	...	....	....	...	....	...	....	....	....
2	80	....	....	80		...	160	...	....	....
3	...	80	....	....	80	....	....	100	....	....
4	...	..	....	....	....	....	....	....	....	...
5	...	...	160	...		160	....	....	50	120
6	80	...	160	80	....	160	160	....	50	120
7	....	....	...	....	....	....	....	....	....	....
8	80	80	....	80	80	...	160	100	....	....
9	....	80	160	....	80	160	....	100	50	120
10	....	....	....	....	....	....	....	....	....	....
Roadway										
11	80	80	160	80	80	160	160	100	50	120
12	80	80	240	80	80	240	160	100	50	200
13	....			....	....	....	....	....	....	....
14	80	80	160	...	....	....	160	100	50	120
15	....	..	....	....	....	....	160	100	50	120
16	....	....	..	....	....	....	....	....	....	...
17	160	80	80	160	80	80	160	100	25	60
18	Barnyard manure, 8 tons each, on corn and wheat									
19	....	....	....	...	....	...	....	....	....	....
20	Barnyard manure, 4 tons each, on corn and wheat									
Roadway										
21	Same elements as 17, but nitrogen in oilmeal									
22	....	....	....	....	...	....	...	....	....	....
23	Same elements as 17, but nitrogen in dried blood									
24	Same elements as 17, but nitrogen in sulphate ammonia									
25	....	....	....	....	...	...	....	...	....	....
26	Same elements as 11, but phosphorus in bone meal									
27	Same elements as 11, but phosphorus in dissolved boneblack									
28	....	...	....	....	....	....	....	.	....	....
29	Same elements as 11, but phosphorus in basic slag									
30	Same elements as 17, but nitrogen in tankage									
Roadway										
31	....	....	....	....	....	....	...	....	...	....
32	Acid phosphate and muriate potash as on 11, nitrate soda one-half as much									
33	Acid phosphate and muriate potash on 11, nitrate soda one fourth as much									
34	....	....	....	....	...	....	...	....	....	...
35	Acid phosphate and nitrate soda as on 11, muriate potash one half as much									
36	Acid phosphate and nitrate soda as on 11, muriate potash one-fourth as much									
37	....	....	....	....	....	....	....	....	....	...
38	Acid phosphate 100, muriate potash 10, tankage (7-30) 100, all on wheat									
39	Barnyard manure, 16 tons, all on wheat									
40	...	....	....	....	....	...	....	....	....	....
Roadway										

Roadway

Roadway

TABLE VIII. The 5-year rotation at Strongsville. Total fertilizing materials and their cost and total and net value of increase produced by 5-year periods and for 17 years, calculated for one rotation of 5 years

Plot No.	Fertilizing materials in pounds per acre for each rotation	Cost of fertilizers for each rotation	Average value of total increase per acre for each rotation[1]				Net gain or loss (—) from fertilizers for each rotation				Plot No.
			First 5 years	Second 5 years	Third 5 years	17 year average	First 5 years	Second 5 years	Third 5 years	17 year average	
2	Acid phosphate, 320	$ 2.60	$14.12	$21.66	$16.05	$17.28	$11.52	$19.06	$13.45	$14.68	2
3	Muriate of potash, 260	6.50	.62	.99	—1.49	0.06	—5.80	—5.57	—5.67	—6.44	3
5	Nitrate of soda, 440; dried blood, 50	14.40	.75	.94	2.48	1.48	—13.65	—13.46	—11.92	—12.92	5
6	Acid phosphate, 320; nitrate of soda, 440; dried blood, 50	17.00	18.21	24.67	22.21	21.46	1.21	7.67	5.21	4.46	6
8	Acid phosphate, 320; muriate of potash, 260	9.10	15.17	19.77	21.10	18.69	6.07	10.67	12.00	9.59	8
9	Muriate of potash, 260; nitrate of soda, 440, dried blood, 50	20.90	3.48	2.87	6.81	4.57	—17.42	—18.03	—14.09	—16.33	9
11	Acid phos., 320; mur. potash, 260; nit. soda, 440; dried blood, 50	23.50	21.69	24.66	23.75	23.32	—1.81	1.16	.25	—0.18	11
12	" " 320; " " 260; " " 680; " " 50	30.70	22.30	26.57	24.22	23.20	—8.40	—4.13	—6.48	—7.50	12
14	" " 240; " " 180; " " 280; " " 50	16.05	18.70	19.44	18.40	18.78	2.65	3.39	2.35	2.73	14
15	" " 160; " " 100; " " 120; " " 50	8.60	.....	13.52	9.92	11.45	......	4.92	1.32	2.85	15
17	" " 480; " " 260; " " 220;[2] " " 25[2]	17.60	15.27	26.80	25.27	22.60	—2.33	9.20	7.67	5.00	17
18	Yard manure, 16 tons	?	19.64	20.18	25.17	21.72	......	......	......	......	18
20	Yard manure, 8 tons	?	12.58	12.64	14.10	13.25	......	......	......	......	20
21	Same elements as 17, but nitrogen in linseed oil meal	17.60	18.52	26.48	20.77	21.51	.92	8.88	3.17	3.91	21
23	" " " 17, " " " dried blood	17.60	20.56	24.16	20.00	21.57	2.96	6.56	2.40	3.97	23
24	" " " 17, " " " sulphate of ammonia	17.60	20.47	24.93	21.60	22.40	2.87	7.33	4.00	4.80	24
26	" " " 11, " phosphorus in bone meal	23.50	20.46	26.02	21.59	23.68	—3.04	2.52	—1.91	0.18	26
27	" " " 11, " " " dissolved bone black	23.50	17.45	24.05	21.22	20.25	—6.05	.55	—2.28	—3.25	27
29	" " " 11, " " " basic slag	23.50	23.20	25.52	21.22	22.96	—.30	2.02	—2.28	—0.54	29
30	" " " 17, " nitrogen in tankage	17.60	24.92	34.34	25.39	27.72	7.32	16.74	7.79	10.12	30
32	Acid phos.; 320; mur., potash, 260; nit. soda, 220; dried blood, 25	16.30	20.97	24.39	20.60	21.81	4.67	8.09	4.30	5.51	32
33	" " 320; " " 260; " " 110; " " 15	12.70	20.45	24.53	18.83	21.35	7.75	11.83	6.13	8.65	33
35	" " 320; " " 130; " " 440; " " 50	20.25	20.35	23.88	23.95	22.77	.10	3.53	3.70	2.52	35
36	" " 320; " " 65; " " 440; " " 50	18.62	22.15	26.81	21.36	23.44	3.53	8.19	2.74	4.82	36
38	" " 100; " " 10; tankage (7-30) 100[1]	3.20	.....	20.38	13.68	14.59	......	17.18	10.48	11.39	38
39	Yard manure, 16 tons	?	.....	14.73	22.72	16.24	......	......	......	......	39
	Av. value of increase from fertilizers containing phosphorus[3]		19.32	24.93	21.53	21.78					

[1]Computing corn at 40 cents per bushel; oats at 30 cents; wheat at 80 cents; stover at $3.00 per ton; straw at $2.00 and hay at $8.00.
[2]Double this quantity during the first 5 years. [3]Excluding Nos. 15 and 38.

After liming Sections E, A and B in this manner the experiment was further modified by applying the finely ground, untreated phosphate rock, known as floats, to the north ends of the plots, the floats being applied in the same quantities and in the same manner as the lime. This treatment apparently had but little immediate effect on the corn, oats or wheat, but a very great increase resulted in the clover crops, as will be shown further on, and these larger crops have been followed by much larger total yields in the corn and wheat. The lower yield of oats is probably due chiefly to seasonal variation, and this may be in part the cause of the differences noted in the wheat yields, but it does not account for the improvement in the clover crops, and the consequent improvement in the corn.

TABLE IX. Average annual yield and increase per acre by periods in 5-year rotation—Strongsville

Crop and treatment		First period	Second period	Third period
Corn: Unfertilized yield..	Bus.	25.73	20.77	32.16
Fertilized yield..	"	31.99	31.81	42.35
Increase from fertilizers.......	"	6.26	11.04	10.19
Oats: Unfertilized yield	"	30.80	38.80	33.93
Fertilized yield......	"	41.28	50.84	40.86
Increase from fertilizers.......	"	10.48	12.04	6.93
Wheat: Unfertilized yield...........	"	4.50	6.74	11.47
Fertilized yield..............	"	11.54	16.65	19.26
Increase from fertilizers.....	"	7.04	9.91	7.78
Clover: Unfertilized yield............	Lbs.	1,467	1,140	2,791
Fertilized yield..............	"	2,941	2,390	3,579
Increase from fertilizers.....	"	1,474	1,250	788
Timothy: Unfertilized yield.........	"	1,379	294	2,397
Fertilized yield	"	1,647	348	2,776
Increase from fertilizers...	"	268	54	379

Returning to Table VIII, it will be observed that while acid phosphate used alone has not given the highest total yield, its low cost has enabled it to give the largest net gain in every period. Where nitrate of soda and muriate of potash have been used separately or in combination with each other only, on Plots 3, 5 and 9, the resulting increase has in every case failed to pay the cost of the fertilizer. Where these salts or other carriers of nitrogen have been added to acid phosphate the increase has been greater than that from acid phosphate used alone, but not enough greater to cover the added cost of the fertilizer; these results thus differing materially from those attained on the Blake land, as shown in Table III, and also from those attained in the similar rotation at Wooster. This outcome at Strongsville is apparently explained by the previous

history of the two tracts of land. They lie on the same rock stratum and have practically the same topography and mechanical and chemical composition, but the Pomeroy land had lain in pasture for a quarter of a century before the experiment began, whereas the Blake land had been under cropping, though with little or no system in rotation of crops or use of manure.

Probably no treatment exhausts the available phosphorus of the soil more rapidly than pasturage, as the formation of bone or the production of milk involves a heavy draft upon this element; but the major part of the nitrogen and potassium consumed in the feed are returned to the soil in the manure. In crop production, however, if both grain and straw or hay are removed from the land, or the entire plant, as in truck farming, there is a relatively large loss of both nitrogen and potassium, as well as of phosphorus.

That the low effect of potassium on the Pomeroy land is exceptional is indicated by Table X, in which is shown the total and net value of increase from phosphorus alone and from phosphorus and potassium in combination in several long-continued experiments:

TABLE X. Value of increase per acre from fertilizers carrying phosphorus alone or phosphorus and potassium in combination*

Station and experiment	Duration of test	Phosphorus alone			Phosphorus and potassium		
		Cost of fertilizers	Value of increase		Cost of fertilizers	Value of increase	
			Total	Net		Total	Net
Strongsville— 5-year rotation............	17 yrs.	$0.52	$ 3.46	$ 2.94	$ 1.82	$ 3.74	$ 1.92
Wooster— 5-year rotation..........	18 yrs.	0.52	3.31	2.79	1.82	4.90	3.08
Wooster— Potatoes-wheat-clover rotation.	18 yrs.	0.87	3.89	3.02	2.53	6.95	4.42
Wooster— Corn-oats-clover rotation........	7 yrs.	0.87	1.58	0.71	1.20	2.66	1.46
Germantown— Corn-wheat-clover rotation.....	9 yrs.	0.63	3.30	2.67	0.97	4.78	3.81
Germantown— Tobacco-wheat-clover rotation..	9 yrs.	1.30	11.11	9.81	2.80	20.08	17.28
Carpenter— Corn-wheat-clover rotation......	9 yrs.	0.63	2.87	2.24	0.97	4.06	3.09
**Penna.— Corn-oats-wheat-clover rotation..	25 yrs.	1.20	2.19	0.99	3.70	5.37	1.67

*The values in this table are computed on the basis of 40 cents per bushel for corn, 30 cents for oats, 80 cents for wheat, 40 cents for potatoes, $3.00 per ton for corn stover, $2.00 for straw, $8.00 for hay and 8 cents per pound for tobacco.
**Pennsylvania State College Experiment Station, Bul. 90.

After a few years' study of the results of the Wooster and Strongsville experiments we became convinced that potassium was being used in larger quantity than necessary and, therefore, when the Germantown and Carpenter tests were begun the proportion of potassium in the fertilizer was materially reduced. The results

thus far attained in these experiments, while demonstrating the necessity for some potassium in the fertilizer, justify the reduction in quantity.

It will be observed that when potassium was used alone, as applied in the muriate, there was a slight reduction in the average yield, and the same thing has happened in the Pennsylvania tests, thus giving ground for the suspicion that an excess of this salt may be actually injurious to the crop, notwithstanding its great value when properly reenforced with phosphorus.

AN EXPERIMENT WITH LIME AND FLOATS

In 1901 and 1902 one-half the land in Sections E and A was dressed with quicklime while it was being prepared for corn, the lime being used at the rate of one ton per acre, and applied to all the plots, fertilized and unfertilized alike. The lime was spread over the inner half of Section "E"; that is, over the north ends of Plots 1 to 20 and over the south ends of Plots 21 to 40. On section A it was spread over the south ends of all the plots.

The corn yields were very low for these seasons, the average unfertilized yields per acre being as below:

	Limed	Unlimed
1901, Section E....................	21.85 bus.	20.89 bus.
1902, Section A....................	19.36 "	19.12 "

No differences in yield which could be ascribed to the lime were found on the fertilized or manured plots, nor was there any conspicuous difference in the appearance of the grain and grass crops following the corn, hence these crops were not harvested separately.

In 1905 this experiment was modified by applying lime to the south half of each section and floats to the north half. That year the lime and floats were applied in the spring to section D, while it was being prepared for corn, and in the fall to Section C, while being prepared for wheat, the dressings being applied in all cases after plowing and before planting. After this year the dressings were given only to the corn crops. For several years the lime and floats were applied in two quantities—one ton per acre on the south half of each half-section, and two tons on the north half, but since 1900 the dressings have been two tons of powdered limestone per acre on the south half of the entire section and one ton of floats per acre on the north half.

The outcome of this experiment, to the end of 1912, is summarized in the tables which follow. In computing these tables the unfertilized yields given are the averages of the actual yields obtained from the 14 unfertilized plots, while the fertilized yields are calculated by adding to this average the increase for each treatment, as found by our regular method of computation from plot to plot, this method of computation being adopted because of variations in natural productiveness between the two ends of the plots and between different parts of the range of plots, due to the differences in soil that invariably occur over areas so large as the 4 acres included in each of these ranges of plots.

While of course it is impossible entirely to eliminate the errors due to these variations, yet the frequent repetition of the unfertilized check plots greatly reduces them, and this method of computation brings the natural inequalities to a common level.

In the tables the plots receiving similar treatment are grouped together: the three manured plots, (18, 20 and 39); the three plots receiving nitrogen and potassium without phosphorus (3, 5 and 9); the 7 plots receiving complete fertilizers containing nitrogen equivalent to that found in 240 pounds of nitrate of soda (17, 21, 23, 24, 30, 32 and 33, No. 33 receiving only half the nitrogen given to the other 6), and the 6 plots receiving complete fertilizers containing nitrogen equivalent to that carried in 480 pounds of nitrate of soda, (11, 26, 27, 29, 35 and 36).

The results of this experiment will first be considered by sections.

SECTION D

This section was dressed with lime and floats in the spring of 1910. The crop yields for the 8 years, 1905 to 1912, inclusive, are shown in Table XI, the oats crop being repeated in 1912 because of the complete destruction of the wheat crop by the severe winter of 1911-12

TABLE XI: Lime and floats on Section D, 5-year rotation, Strongsville

Year	Crop	Plots and treatment and yield per acre									
		Unfertilized		18, 20, 39 Yard manure		3, 5, 9 Nitrogen or potassium, no phosphorus		17—33 Complete fertilizer low nitrogen		11—36 Complete fertilizer high nitrogen	
		Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats
1905	Corn, bus....	38.25	35.15	52.86	51.65	38.23	34.64	54.67	52.83	51.86	49.01
1906	Oats, bus ...	30.21	39.50	30.28	43.89	31.95	39.76	43.01	46.96	41.86	48.68
1907	Wheat, bus...	12.09	14.09	31.43	25.70	11.80	12.61	25.18	22.11	29.37	25.62
1908	Clover, lbs...	2,441	5,117	3,946	5,226	3,038	5,503	3,725	5,325	3,961	5,576
1909	Timothy, lbs.	1,853	4,604	2,155	4,305	2,091	3,758	2,041	4,642	2,383	4,548
1910	Corn, bus....	9.70	17.46	16.15	19.14	10.27	18.79	12.60	18.57	12.18	19.67
1911	Oats, bus....	40.36	49.23	50.61	54.40	42.20	54.24	52.69	58.53	54.08	59.90
1912	Oats, bus....	31.84	42.56	43.36	49.29	31.51	44.80	43.48	50.67	41.47	51.72

The table shows that the corn crop of 1905 gave a larger yield on the limed land than on that dressed with floats in every case, while the oats following the corn was heavier in every case on the floats-treated land.

The wheat crop of 1907 yielded about two bushels per acre more after floats than after lime on the unfertilized land, and nearly one bushel more on Plots 3, 5 and 9, but on the manured land and that receiving complete fertilizers the larger yields were harvested from the limed land.

The clover and timothy crops of 1908 and 1909 showed very much larger yields on the land treated with floats than on that dressed with lime, and this superiority continued through the corn and oats crops of 1910, 1911 and 1912.

Clover was sown in the last oats crop, and its fall growth was very much larger on the limed land than on that treated with floats, thus indicating a reversal of the outcome found in the previous clover crops. In one case, however, the fall appearance has been deceptive, the greater weight of hay having been harvested from the floats-treated land on Section A in 1910, although the clover stand was much better the preceding fall on the limed land.

SECTION C

This section was dressed with lime and floats in September, 1905, while preparing the land for wheat, and again in the spring of 1909, for the corn crop. The results are shown in Table XII.

TABLE XII. Lime and floats on Section C, 5-year rotation, Strongsville

Year	Crop	Plots and treatment and yield per acre									
		Unfertilized		18, 20, 39 Yard manure		3, 5, 9 Nitrogen or potassium no phosphorus		17—33 Complete fertilizer low nitrogen		11—36 Complete fertilizer high nitrogen	
		Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats
1906	Wheat, bus..	3.23	3.52	14.09	14.73	4.32	7.11	18.99	16.99	19.46	18.44
1607	Clover, lbs...	3,038	3,850	4,880	4,897	3,418	4,408	4,240	4.101	4,400	4,173
1908	Timothy, lbs.	3,084	2.706	4,139	3.908	3,056	3,109	3,938	3,382	4.171	3,402
1909	Corn, bus....	30.78	33.18	50.34	49.75	29.82	39.39	54.49	50.15	52.25	45.93
1910	Oats, bus....	31.62	37.35	36.38	42.99	34.56	34.03	34.36	38.42	34.11	38.18
1911	Wheat, bus..	6.38	7.31	14.84	14.60	5.39	7.37	16.33	12.20	14.20	11.18
1912	Clover, lbs...	2,531	2,512	5,066	4,894	2,365	2,756	4,293	2,808	3,879	2,831

The table shows but a very small difference in the effect of the two dressings on the unfertilized wheat and on that grown on manured land. On the land receiving fertilizers carrying nitrogen or potassium but no phosphorus, (Plots 3, 5 and 9) there is a marked increase from the floats, while on the land receiving the complete fertilizers the limed land produced more wheat than that treated with floats.

In the clover crop of 1907 the yield was decidedly larger after floats on the unfertilized land and on Plots 3, 5 and 9, but on the manured land the yield was practically the same for the two treatments, and on that receiving the complete fertilizers it was a little larger after lime than after floats.

The timothy crop of 1908 shows a larger yield on the limed land under all the treatments except on the land receiving nitrogen or potassium, but no phosphorus.

Taking the second rotation, the corn crop of 1909 shows a slightly larger yield after floats on the unfertilized land and a gain of nearly 10 bushels per acre on Plots 3, 5, and 9, but on the manured land the yields are practically the same and on the land receiving complete fertilizers the limed part shows the larger yields.

The oats crop, however, is from 4 to 6 bushels per acre larger on the floats-treated land under all the treatments except on Plots 3, 5 and 9; but this apparent exception to the general rule may be due to the method of calculation, as the actual yields were greater on the floats ends of these plots than on the limed ends.

The wheat crop of 1911 shows a larger yield after lime than after floats on all the land except the unfertilized plots and those receiving no phosphorus, and here the differences are small.

The clover crop of 1912 was conspicuously better on the limed land, the difference being evident as far as the field could be seen. Even where the total weights appear to be nearly the same, as on the unfertilized land and on Plots 3, 5 and 9, the hay on the unlimed land contained more weeds and less clover than on the limed land.

SECTION B

This section (see table XIII) was dressed with lime and floats for the corn crop of 1908. The season was unfavorable and the yield very low, being a little greater after floats than after lime on the unfertilized land, on Plots 3, 5 and 9, and on the series receiving the complete fertilizer low in nitrogen.

TABLE XIII: Lime and floats on Section B, 5-year rotation, Strongsville

Year	Crop	Plots and treatment and yield per acre									
		Unfertilized		18, 20, 39 Yard manure		3, 5, 9 Nitrogen or potassium no phosphorus		17—33 Complete fertilizers low nitrogen		11—36 Complete fertilizers high nitrogen	
		Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats
1908	Corn, bus....	17.37	18.78	24.99	23.12	15.48	20.26	24.35	29.06	27.04	27.45
1909	Oats, bus....	38.56	39.51	43.68	43.30	41.25	41.10	53.00	58.16	52.23	52.91
1910	Wheat, bus..	8.91	8.13	13.56	13.12	10.65	7.22	17.86	17.18	18.72	17.09
1911	Clover, lbs...	1,966	2,029	2,383	2,902	2,157	2,247	1,666	2,877	2,442	3,197

The oats crop of 1909 gave a fair yield, but showed no marked difference between the two treatments except on the plots receiving the complete fertilizer low in nitrogen.

The wheat crop of 1910 was very slightly better on all the limed plots, and decidedly so on Plots 3, 5 and 9.

The clover yields in 1911 were slightly higher on the floats-treated ends of the unfertilized plots and on Plots, 3, 5 and 9, and decidedly higher on the plots receiving manure and complete fertilizers.

The timothy sown with this clover was so complete a failure in 1912 that it was not harvested. This failure of the timothy crop has been common on this land, only 7 crops having been harvested in 16 years, although this is the first failure since the use of lime and floats was begun. The land is infested with Spiked Oat grass ("Poverty grass"), which takes possession as soon as cultivation ceases, and crowds out the timothy.

This section has had but the one application of the lime and floats, and hence there has not been opportunity for the cumulative effect, which seems to be manifest on the othef tracts.

SECTION A

As stated above, this section was dressed with lime on the south half in 1902, but without apparent effect. In 1907 lime and floats were applied, and the history of the crops harvested since is shown in Table XIV.

TABLE XIV. Lime and floats on Section A, 5-year rotation, Strongsville

Year	Crop	Plots and treatment and yield per acre									
		Unfertilized		18, 20, 39 Yard manure		3, 5, 9 Nitrogen or potassium no phosphorus		17—33 Complete fertilizer low nitrogen		11—36 Complete fertilizer high nitrogen	
		Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats
1907	Corn, bus....	17.56	23.23	23.49	26.42	20.78	26.27	27.16	22.54	25.42	29.01
1908	Oats, bus....	27.90	36.14	40.12	54.36	35.11	52.29	48.85	60.01	44.90	55.87
1909	Wheat, bus..	11.29	17.26	17.73	20.30	11.93	17.85	20.61	20.02	20.42	20.07
1910	Clover, lbs...	1,938	4,743	3,450	5,347	1,955	4,691	3,536	4,760	3.467	5,309
1911	Timothy, lbs.	2,301	4,249	2,882	4,149	2,125	3,287	3,069	4,482	2,871	4,436
1912	Corn, bus....	35.84	43.40	47.95	43.08	45.10	52.83	57,35	47.55	55.65	56.41

The corn produced but half a crop in 1907, and the yields appear to have been 3 to 5 bushels greater on the floats-treated land in most cases. The yields of the individual plots were so irregular, however, that the averages are less satisfactory than is desirable.

The following oats crop of 1908, however, was definitely better in the average on the floats-treated land in every case, and there are no contradictions in the individual plots.

The wheat crop of 1909 was decidedly better after floats on the unfertilized land, on that dressed with manure, and on Plots, 3, 5 and 9, but on the land receiving fertilizers containing phosphorus the yields were practically the same for both lime and floats.

The hay crop of 1910 was more than twice as heavy on the floats-treated ends of the unfertilized plots and on Plots 3, 5 and 9 as on the limed ends, and was from 30 to 50 percent greater on the manured land and that treated with complete fertilizers, and this notwithstanding the fact that the fall growth of clover was better on the limed land.

The timothy following the clover was also much heavier on the floats-treated land than on that dressed with lime.

The corn crop of 1912 was larger after floats than after lime on the unfertilized land and on that receiving nitrogen or potassium but no phosphorus, the average difference in both cases amounting to about 7½ bushels per acre; but on the manured plots and on the low nitrogen and high phosphorus plots, 17 to 33, the limed land produced the most corn.

AVERAGE YIELD OF EACH CROP

The average yields, throughout the entire period of the experiment, of each of the 5 crops of the rotation are collected in Table XV; these averages including 6 crops each of corn, oats, wheat and clover and 3 crops of timothy grown in 4 years and averaged as 4 crops.

TABLE XV. Lime and floats, 5-year rotation, Strongsville. Average comparative yield per acre

Corn	Plots and treatment and yield per acre									
	Unfertilized		18, 20, 30 Yard manure		3, 5, 9 Nitrogen or potassium no phosphorus		17—33 Complete fertilizer low nitrogen		11—36 Complete fertilizer high nitrogen	
	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats
Corn, bus	24.92	28.53	35.96	35.53	26.61	32.03	38.44	36.78	37.40	37.81
Oats, bus	33.41	40.71	40.74	48.04	36.10	44.37	45.90	52.13	44.27	51.21
Wheat, bus	8.38	10.06	18.33	17.69	8.82	10.43	19.79	17.70	20.43	18.48
Clover, lbs	2,383	3,650	3,945	4,653	2,587	3,921	3,604	3,974	3,630	4.217
Timothy, lbs	1,809	2,890	2,294	3,090	1,818	2,539	2,262	3,126	2,356	3,096

This table shows that on the unfertilized land and on that receiving fertilizers containing no phosphorus the larger average yield has followed the dressing of floats in every case. On the manured land and on that receiving a complete fertilizer in which the ratio of nitrogen to phosphorus is relatively high the average corn yields differ by less than half a bushel per acre—too small a difference to have any significance. In both cases the wheat yields are slightly

larger on the limed land. The clover and timothy yields, however, are distinctly heavier on the floats-treated land. On the land receiving the low-nitrogen and high-phosphorus fertilizer the corn and wheat crops are each about two bushels per acre greater on the limed land, but the oats clover and timothy are heavier on the floats-treated land.

Taking the experiment as a whole, it is evident that the floats has served as a source of phosphorus to crops grown on a soil deficient in that element. That the phosphorus in the floats has become available slowly is shown by the relatively small effect on the corn crop, and yet the earlier history of these experiments shows a similar slowness in the action of acid phosphate, as the average increase for the first 5 crops of corn grown on this land, (1895 to 1899)—the corn being grown on previously unfertilized land each season—was less than 4 bushels per acre, as against an increase of 10 bushels per acre for the 5 crops of oats immediately following the corn and of 13 bushels of corn for the second 5 crops of corn (1900 to 1904).

It does not appear that the larger amount of organic matter furnished by the manure has materially increased the effectiveness of the floats, the manure in these experiments having been plowed under before the application of the floats. This result is in strong contrast to the outcome of the experiment described in Bulletin 183 and summarized in the annual circulars following, in which the floats is incorporated with the manure before being spread on the land.

The inference that the chief function of the floats in the Strongsville test has been the purveying of phosphorus is further supported by the marked gain from floats over lime on the land which has received fertilizers containing nitrogen or potassium but no phosphorus (Plots 3, 5 and 9), as compared with the relatively small gains on the land receiving the same fertilizers, with phosphorus in addition. The importance of phosphorus is strikingly brought out by comparing the yields on the limed ends of plots 3, 5 and 9 with those on the limed ends of the plots receiving complete fertilizers.

In the earlier years of this experiment the large hay crops harvested on the floats-treated land supported the assumption that the floats was not only serving as a source of phosphorus, but was also taking the place of lime in correcting soil acidity; but the clover crop of 1912 showed beyond question that this is not the case; the clover being practically restricted to the limed land, and the larger part of the weights reported from the floats-treated land consisting of weeds, timothy and other grasses. Even on the manured plots,

where the growth of clover was larger than elsewhere, the chief component of the hay was timothy. Judging from the late summer and fall appearance, the clover crop of 1913 will be a repetition of that of 1912; but, as before stated, the fall appearance is sometimes deceptive.

THE FINANCIAL OUTCOME

The cost of floats, delivered at average Ohio points, is about $7.50 per ton in bulk carloads. That of powdered limestone will average approximately $2.00 per ton. The cost of hauling to the farm and spreading on the land may be estimated at $1.00 per ton for farms averaging not more than 3 miles from the railway station. The cost of dressing an acre with floats at the rate used in these experiments will, therefore, be about $8.50, and that of a 2-ton dressing of powdered limestone about $6.00. The prudent farmer will hesitate to incur such expenditures without a reasonable assurance of a profitable return.

It was not practicable in this case to leave any of the land entirely without the cross dressings of lime and floats, and therefore we have no direct comparison with untreated land; but the following comparison of the unfertilized yields in this rotation for the 5 years immediately preceding the beginning of the cross dressings, with the yields harvested since, is believed to be approximately fair.

TABLE XVI. Unfertilized yields before and after cross dressing

	Before	After	
		Lime	Floats
Corn, bus	20.77	24.92	28.53
Oats, bus	38.80	33.41	40.71
Wheat, bus	6.74	8.38	10.06
Clover, lbs	1,250	2,383	3,650
Timothy, lbs	704	1,809	2,890
Total value	$37.19	$47.91	$63.05

The table shows that the average yield of oats was larger during the earlier period than on the limed land during the later period, a difference undoubtedly due to seasonal variation; but all the other crops, and especially the clover and timothy, show much larger yields after the cross dressing was begun.*

The values given are computed at the rate of half a dollar per bushel for corn, one-third of a dollar for oats, 90 cents for wheat and $8.00 per ton for hay. At these valuations, and assuming that the

*Not only has the floats increased the weight of crop but it has also improved the quality, as shown by the analyses of wheat grain grown in these experiments made under supervision of Mr. J. W. Ames, and reported in Bulletin 221. These analyses show a larger percentage of phosphorus in the grain grown on the floats-treated than on the limed land, the differences being greater on the unfertilized land and on Plots 3, 5 and 9 than on the land receiving manure or fertilizers containing phosphorus.

differences in yield are due to the treatment, to which it is believed they must be chiefly ascribed, there has been an ample margin to pay for one dressing in each rotation of either lime or floats, the margin being much larger in the case of floats than in that of lime.

In Table XVII the same valuations are applied to the average of all the crops grown under the different treatments since the use of lime and floats was begun, as given in Table XV, and from the total values for each rotation thus computed the cost of treatment with fertilizers, lime and floats is deducted, the manure being computed at one dollar per ton, spread upon the land, the fertilizers at $60.00 per ton for nitrate of soda, $50.00 for muriate of potash and $16.25 for the 14 percent grade of acid phosphate—these prices for fertilizing materials being sufficiently above the necessary cost to amply cover the cost of mixing and application.

The table shows that, at these valuations, there has been a larger net gain from the floats than from the lime in every case, notwithstanding the greater cost of the floats, although the difference is small on the manured land and on that receiving complete fertilizers; and that the land receiving complete fertilizers in addition to the lime and floats, notwithstanding their high cost, has returned a much larger net gain than that receiving lime alone.*

*The Strongsville farm is near the southwestern corner of Cuyahoga county, and near the geographical center of the group of three counties, Cuyhaoga, Lorain and Medina. The 5-year average yields in bushels per acre of corn, oats and wheat for these counties for the periods before and after this experiment was begun were as follows:

County	Average yield per acre		
	First period		
	Corn	Oats	Wheat
Cuyahoga	28.9	40.3	18.7
Lorain	29.9	38.3	19.9
Medina	33.6	40.2	19.5
	Second period		
Cuyhoga	33.9	38.6	20.2
Lorain	34.7	35.5	20.0
Medina	35.9	34.1	19.0

These statistics show an increased yield of corn in each county during the second period, as compared with the first; a decreased yield of oats; a slight increase in the yield of wheat in Cuyahoga county, and a practically stationary yield in Lorain and Medina.

Two questions of importance are still to be considered, namely: does the floats fully satisfy the demand of the land for lime? and will it prove a cheaper source of phosphorus than acid phosphate?

These questions cannot be fully answered. As has already been stated, the clover crop of 1912 on the limed land was far superior to that on the land treated with floats, and the new seeding of that year indicated same outcome for 1913.

TABLE XVII. Lime and floats, 5-year rotation, Strongsville
Financial outcome

	Plots, treatment, and average value of crops per acre									
	Unfertilized		18, 20, 39 Yard manure		3, 5, 9 Nitrogen or potassium no phosphorus		17—33 Complete fertilizer low nitrogen		11—36 Complete fertilizer high nitrogen	
	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats
Corn	$12.46	$14.26	$17.98	$17.76	$13.30	$16.01	$19.22	$18.39	$18.70	$18.95
Oats	11.14	13.57	13.58	16.01	12.03	14.79	15.30	17.38	14.76	17.07
Wheat	7.54	9.05	16.50	15.74	7.94	9.37	17.81	15.93	18.39	16.63
Clover	9.53	14.80	15.78	18.61	10.35	15.68	14.01	15.90	14.52	16.87
Timothy	7.24	11.56	9.18	12.36	7.27	10.16	9.05	12.50	9.42	12.38
Total value	47.91	63.05	73.02	80.48	50.89	66.00	75.39	80.10	75.79	81.90
Cost of fertilizers	.....	.....	13.33	13.33	13.93	13.93	15.03	15.03	22.15	22.15
Cost of lime & floats	6.00	8.50	6.00	8.50	6.00	8.50	6.00	8.50	6.00	8.50
Balance	41.91	54.55	53.69	58.65	30.96	44.07	54.36	56.57	47.64	51.15

As a tentative comparison of the effect of acid phosphate and floats, let us again compare the results attained during the 5 years immediately preceding the use of lime and floats with those shown since, as in Table XVIII.

TABLE XVIII. Lime and floats, 5-year rotation, Strongsville. Comparison of effect of acid phosphate and floats. Yields per acre

Crop	Before cross dressing			After cross dressing					
				With lime			With floats		
	Unfertilized yield	Increase for acid phosphate	Computed yield per acre	Unfertilized yield	Increase for acid phosphate	Computed yield per acre	Unfertilized yield	Increase for acid phosphate	Computed yield per acre
Corn, bus	20.77	13.37	34.14	24.92	13.37	38.29	28.53	3.35	31.88
Oats, bus	38.80	11.04	49.84	33.41	11.61	45.01	40.71	5.06	45.77
Wheat, bus	6.74	8.77	15.51	8.38	8.07	16.45	10.06	4.52	14.58
Clover, lbs	1,250	9.39	2,189	2,383	1,925	4,308	3,650	2.07	3,863
Timothy, lbs	704	1.68	872	1,809	411	2,220	2,890	—1.71	2,719
Total value	$37.19	$22.68	$59.87	$47.91	$27.17	$75.08	$63.05	$7.58	$70.63
Cost of treatment	....	2.60	....	....	2.60	....	. ..	....	....
Net gain	....	20.08	....	....	24.57	....	....	....	....

The table shows that the value of the unfertilized crops of a rotation for the average of the five years preceding the cross dressing with lime and floats amounted to $37.19. The application of 320 pounds of acid phosphate alone (on Plot 2) increased this value by $22.68, or to a total value, as found by adding the increase from acid phosphate to that of the average unfertilized yields, of $59.87.

During the next period the land cross-dressed with lime, but receiving no fertilizer, produced crops to the average value per rotation of $47.91, or $10.72 more than that previously produced on unfertilized and unlimed land, while the addition of acid phosphate to the lime, used in the same quantity as before, produced a further increase amounting to $27.17, making a total gain for lime and acid phosphate combined of $37.89, or doubling the previous unfertilized yield and raising the total value of the produce of the average rotation to $75.08. The increase of the acid phosphate plot during this period was considerably greater than during the previous period, and it will be observed that this gain in increase is nearly all accounted for in the clover crop, the increase in this crop being nearly 1,000 pounds per acre greater after the liming than before, notwithstanding the fact that the unfertilized clover yield was nearly doubled, bringing the total yield for lime and acid phosphate up to 4,308 pounds per acre, as against a previous unfertilized and unlimed yield of 1,250 pounds.

During this period the land treated with floats, but otherwise unfertilized, produced crops having a total average value of $63.05 for each rotation, or $25.86 more than the land receiving no fertilizer had yielded during the previous period, thus indicating for the ton of floats practically the same effectiveness as that realized from 320 pounds of acid phosphate on limed land.

The further addition of acid phosphate to land dressed with floats has produced an additional yield, thus showing that the floats has not furnished a sufficient supply of available phosphorus to meet the demands of the crops for this element, on this phosphorus-hungry soil.

The additional crops produced by combining the dressing of a ton of floats with 320 pounds of acid phosphate have had a value of $7.58, bringing the value of the total produce up to $70.63 as against a total value of $75.08 for the application of the same quantity of acid phosphate, following a dressing of a ton of lime, or two tons of pulverized limestone.

This outcome is not inconsistent with the results shown in Table XVII, in which the floats, when applied to the land also receiving available nitrogen, either in manure or fertilizers, has caused a larger yield than that given by lime. The explanation is found in the interdependence of the elements.

The soil upon which these experiments are being conducted is so deficient in phosphorus, as compared with nitrogen and potassium, that the addition of these elements produces comparatively little effect unless phosphorus also is added, as shown by the outcome on Plots 3, 5 and 9, as compared with that on the plots receiving complete fertilizers. On the other hand, while phosphorus produces a relatively large increase where used alone, its full effect is not realized until nitrogen and potassium are added. In the complete fertilizers used in this experiment the ratio of phosphorus to nitrogen and potassium, especially to potassium, has been low for this soil, and therefore the phosphorus in the floats has been more fully utilized than would be the case on the land receiving phosphorus only, without nitrogen or potassium.

But the land needs not only phosphorus, potassium and nitrogen, but lime also; the need for lime, so far as the clover crop is concerned, being even more urgent than that for phosphorus. Consequently, the combination of phosphorus and lime is more effective than larger applications of phosphorus without lime.

While the data furnished by this experiment are not sufficiently definite to justify final conclusions, the assumption that floats is a less economic carrier of phosphorus than acid phosphate, when used as a direct application to the land, is supported by an experiment begun at Wooster in 1905 and still in progress, the plan and progress of which are reported in Circulars 104, 114, 120 and 131. Following is a summary of the outcome of this test for the 8 years, 1905-1912:

Plot	Treatment	Net value of increase for one rotation
17	Caustic lime, 1,000 lbs.; acid phosphate, 320 lbs.; muriate of potash, 40 lbs	$11.90
18	Caustic lime, 1,000 lbs.; floats, 320 lbs.; muriate of potash, 40 lbs	10.23
21	Acid phosphate, 320 lbs; muriate of potash, 40 lbs	4.78
24	Floats, 320 lbs; muriate of potash, 40 lbs	1.70
20	Acid phosphate, 320 lbs	2.57
23	Floats, 320 lbs	.98

In this statement the cost of the acid phosphate and floats has been deducted from the total increase, at the rate of $2.60 per acre for the acid phosphate and $1.30 for the floats, but even at double the cost per acre the acid phosphate has been thus far the more economical carrier of phosphorus.

An experiment in the reenforcement of manure with various materials has been in progress at Wooster since 1897, the full plan and results of which have been reported in Bulletin 183 and the supplementary annual Circulars 92, 104, 114, 120 and 131. Up to the end of 1912 there have been harvested in this experiment 15 crops each of corn and wheat and 12 crops of clover, the average value of which, as actually harvested for the two kinds of manure and for each three-year rotation, is $61.32 per acre for the untreated manure, $71.84 for the manure reenforced with floats, and $70.73 for that treated with acid phosphate. This method of reckoning, however, makes no allowance for inequalities of soil. Reckoned according to the method followed in all other experiments of this Station, and employed in the previous comparisons in this bulletin, the values would be $61.97 for the untreated manure $70. 97 for that treated with floats, and $74.65 for that treated with acid phosphate, the cost of treatment being deducted in every case.

By either method of calculation it is clear that the phosphatic materials have greatly increased the effectiveness of the manure for soils needing phosphorus, and it is evident that the floats is being far more effectively used as a reenforcement of manure than as a direct application to the land.

SUMMARY

These experiments, which are still in progress, were begun in 1895 on a cold, heavy clay, lying over compact, argillaceous shales. Part of the land had been in pasture for many years before the experiments were begun, and part under tillage.

Wherever phosphorus has been applied on this land, whether carried in acid phosphate, bonemeal or raw phosphate rock, it has produced a profitable increase of crop.

Nitrogen and potassium, while increasing the crop, have produced a smaller effect than phosphorus, especially in the earlier years of the work. During more recent years there has been a slowly increasing effect from these elements.

While nitrate of soda and muriate of potash have been used at a loss, the fact that the largest yields of crops have been harvested only when the fertilizer has carried nitrogen and potassium in some form indicates the necessity of supplying these elements in some cheaper carrier than chemicals.

For eight years several brands of factory mixed fertilizers were compared with home-mixtures of equivalent composition, made of tankage, acid phosphate and muriate of potash. The outcome of this test was a greater increase of crop from the home mixtures than from the factory mixtures in every case, while the cost of the home mixtures was much less than that of the factory mixtures.

Acid phosphate and steamed bonemeal have been the most effective carriers of phosphorus. Apparently there has been very little difference in effectiveness between the pound of "available" phosphorus in acid phosphate and the pound of total phosphorus in steamed bonemeal.

Steamed bonemeal has been more effective than raw bonemeal, a result which may have been due in part to the finer grinding of the steamed meal and in part to the low effect of nitrogenous fertilizers on this soil.

Raw phosphate rock appears to have been effective in proportion to the "available" phosphorus contained. When applied at the rate of 2,000 pounds per acre every five years raw phosphate rock has produced a greater increase in the cereal crops than raw limestone in twice that quantity. In the earlier experiments clover was benefitted by the phosphate rock; but in more recent years the clover has failed on the phosphated land, though growing with increasing luxuriance on that receiving limestone.

As a direct application to the land, therefore, acid phosphate and steamed bonemeal have been found to be more economical sources of phosphorus than raw phosphate rock.

Lime is as urgently needed on this land as phosphorus, it having become practically impossible to grow clover until lime has been applied, no matter how thoroughly the land was manured or fertilized.

CONCLUSIONS

The following suggestions as to general farm practice on soils similar in character to that on which these experiments have been conducted seem to be justified:

Drainage: Much of this land was so waterlogged that it was impossible to produce a profitable crop of any kind, grain or grass, until the water was removed by drainage.

Liming: Lime was not introduced in these experiments until they had been in progress several years, but the outcome has shown that liming should have been the next step after drainage, as no combination of fertilizers or manures has produced a full crop until lime was added. The results indicate that the first application of lime should have been still larger than the one ton of burnt lime or

two tons of ground limestone actually used in the experiments. When the demand for lime is once satisfied, then smaller applications may follow.

Fertilizing: Apparently all the land in Ohio which has been in cultivation for any considerable length of time is in need of phosphorus, and this need appears to be especially urgent in the northeastern counties. The phosphorus supply stands next to lime in importance.

Crop rotation: Phosphorus alone, however, will not maintain fertility. Nitrogen and potassium must be supplied in some form. Nitrate of soda is the most effective of all artificial carriers of nitrogen in proportion to cost; but under ordinary farm conditions it will be found necessary to maintain the nitrogen supply from some cheaper source than the fertilizer sack if profit is to be secured. Hence the importance of a systematic rotation of crops, including clover or similar nitrogen-gathering crops, and of careful saving and use of animal manure. Under such a system the deficiency of potassium will be so small that it may be covered by moderate purchases of potassium salts.

Lime again: But clover cannot be grown successfully on a soil deficient in lime, and on thousands of acres in eastern Ohio clover is making a weak and sickly growth, or is failing altogether, because of this deficiency; and as clover fails the yields of other crops become more irregular. Lime, therefore, is the foundation of soil fertility, but it is only the foundation. Indirectly, lime increases the nitrogen supply through clover, but it adds neither phosphorus nor potassium. After the foundation is laid, then these become necessary to the superstructure. All are required to complete the edifice, each supplementing and reenforcing the others.

The Director of the Station is responsible for the plan of these experiments and for this discussion of results. The field work has been faithfully conducted by Edward Mohn, Manager of the Northeastern Test-farm, throughout the entire period of the investigations.

APPENDIX

TABLE XIX. Corn in 5-year rotation at Strongsville. Average annual yield per acre by periods

Plot No.	Fertilizers in pounds per acre			5 years 1895-99		5 years 1900-04		5 years 1905-09		17 years 1895-1911		Pl't No.
	Acid phosphate	Muriate of potash	Nitrate of soda	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	
1	...	..	...	24.84	1,311	16.39	1,390	25.90	1,499	21.91	1,416	1
2	80	..	...	27.43	1,275	29.92	1,671	33.21	1,618	30.02	1,598	2
3	...	80	...	23.03	1,209	17.01	1,476	24.26	1,535	21.72	1,505	3
4	...	..	...	20.66	1,153	16.86	1,385	22.59	1,355	20.77	1,398	4
5	...	..	160	22.32	1,206	19.43	1,546	27.44	1,615	23.69	1,561	5
6	80	..	160	29.41	1,305	34.04	1,866	40.04	1,992	34.26	1,782	6
7	...	..	...	23.86	1,314	23.61	1,616	31.88	1,744	26.19	1,625	7
8	80	80	...	28.72	1,207	33.88	1,920	45.35	2,319	35.63	1,883	8
9	...	80	160	25.94	1,293	23.01	1,724	36.09	1,948	28.21	1,722	9
10	...	..	...	24.81	1,302	21.68	1,540	31.85	1,726	25.82	1,583	10
11	80	80	160	35.10	1,566	34.62	2,053	44.03	2,300	37.33	2,026	11
12	80	80	240	33.79	1,590	34.43	2,028	44.87	2,351	36.94	2,042	12
13	...	..	...	27.37	1,374	21.40	1,592	30.90	1,791	26.16	1,636	13
14	[1]80	80	160	35.74	1,684	32.01	1,989	40.08	2,168	35.19	2,003	14
15	[2]...	..	...	28.74	1,435	27.91	1,704	32.48	1,767	28.77	1,695	15
16	...	..	...	30.37	1,567	22.32	1,648	30.47	1,702	27.06	1,677	16
17	160	80	80	33.07	1,597	36.29	1,966	45.21	2,343	37.62	2,023	17
18	[3]...	..	...	38.16	1,723	33.93	2,018	47.40	2,506	39.36	2,154	18
19	...	..	...	26.57	1,551	18.62	1,580	28.79	1,648	24.70	1,660	19
20	[4]...	..	...	33.47	1,670	29.02	1,836	38.14	2,183	33.52	1,957	20
21	145	75	[5]...	29.96	1,634	35.25	2,074	43.58	2,353	35.69	2,050	21
22	...	..	...	25.96	1,550	24.35	1,673	31.34	1,884	27.04	1,753	22
23	150	80	[6]...	32.66	1,568	37.96	2,170	42.88	2,365	37.61	2,099	23
24	160	80	[7]...	32.70	1,670	35.81	2,214	42.18	2,267	36.76	2,120	24
25	...	..	...	26.03	1,536	23.98	1,692	30.99	1,858	26.56	1,750	25
26	[8]...	80	150	30.88	1,728	34.85	2,002	42.12	2,396	35.23	2,083	26
27	[9]...	80	160	30.60	1,674	33.07	1,974	41.29	2,292	34.06	2,016	27
28	...	..	...	24.02	1,426	22.31	1,690	29.28	1,769	24.62	1,670	28
29	[10]...	80	160	33.81	1,604	35.85	2,116	40.36	2,266	35.48	2,029	29
30	[11]...	80	[11]...	38.12	1,652	42.42	2,274	46.67	2,371	41.11	2,134	30
31	...	..	...	25.01	1,419	21.58	1,624	28.53	1,743	24.68	1,638	31
32	80	80	80	28.63	1,356	33.15	2,004	39.89	2,263	33.57	1,981	32
33	80	80	40	28.77	1,317	33.93	2,017	39.00	2,234	34.15	1,972	33
34	...	..	...	21.64	1,282	19.04	1,524	28.71	1,748	23.38	1,602	34
35	80	40	160	29.32	1,419	29.68	1,862	41.80	2,250	33.79	1,943	35
36	80	20	160	33.50	1,590	33.92	2,052	40.78	2,243	36.01	2,045	36
37	...	..	...	25.79	1,301	21.71	1,566	30.70	1,847	25.95	1,641	37
38	[12]...	..	...	27.18	1,390	38.32	1,891	34.80	2,016	30.30	1,837	38
39	[13]...	..	...	24.32	1,265	27.55	1,775	35.79	1,977	30.42	1,797	39
40	...	..	...	24.09	1,279	19.37	1,498	27.15	1,788	23.35	1,569	40
Average unfertilized yield....				25.73	1,424	20.77	1,570	32.16	1,868	25.90	1,684	
Average fertilized yield.......				31.99	1,543	31.81	1,923	39.61	21.52	35.34	2,018	

[1]Fertilized on corn and wheat only. [2]Fertilized on wheat only. [3]Barnyard manure, 8 tons each on corn and wheat. [4]Barnyard manure, 4 tons each on corn and wheat. [5]Linseed oilmeal, 230 lbs. [6]Dried blood, 100 lbs. [7]Sulphate of ammonia, 60 lbs. [8]Bonemeal, 55 lbs. [9]Dissolved boneblack 16 percent, 140 lbs. [10]Basic slag, 17 percent, 65 lbs. [11]Tankage, carrying phosphorus and nitrogen equivalent to Plots 17, 21, 23 and 24. [12]Fertilized on wheat only. [13]Manured on wheat only.

TABLE XX. Corn in 5-year rotation at Strongsville. Average annual increase per acre by periods

Plot No.	Fertilizing elements per acre			5 years 1895-99		5 years 1900-04		5 years 1905-09		17 years 1895-1911		Pl't No.
	Phosphorus Lbs.	Potassium Lbs.	Nitrogen Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	
2	5	..	..	3.98	17	13.37	289	8.41	227	8.49	188	2
3	..	33	..	0.96	3	0.30	94	C.56	132	0.57	101	3
5	..	..	25	0.59	−1	0.32	84	1.75	130	1.10	87	5
6	5	..	25	6.62	44	12.68	327	11.26	378	9.88	231	6
8	5	33	..	4.54	−103	10.91	329	13.49	580	9 56	272	8
9	..	33	25	1.45	−13	0.68	159	4.23	216	2.27	125	9
11	5	33	25	9.43	240	13.03	496	12.50	556	11.40	427	11
12	5	33	37	7.27	240	12.94	453	13.65	588	10.89	421	12
14	5	33	25	7.37	246	10.30	378	9.32	413	8.73	353	14
15	..	..	..	....	...	5.90	74	1.84	39	2.01	73	15
17	10	33	12.5	3.97	35	15.70	341	15.30	659	11.31	352	17
18	20*	60*	75*	10.32	167	14.08	415	18.06	840	13.87	489	18
20	10*	30*	37*	6.06	85	8.76	256	7.81	459	8.10	268	20
21	10	33	12.5	4.85	117	12.52	525	13.09	539	9.43	332	21
23	10	33	12.5	6.69	23	13.73	490	11.66	490	10.73	351	23
24	10	33	12.5	6.69	129	11.71	529	11.07	400	10.04	371	24
26	5	33	25	5.53	229	11.42	314	11.71	568	9.32	360	26
27	5	33	25	5.91	211	10.20	290	11.44	493	8.79	319	27
29	5	33	25	9.46	181	13.78	455	11.33	506	10.84	369	29
30	10	33	12.5	13.44	230	20.58	631	17.86	620	16.45	485	30
32	5	33	12.5	8.08	163	12.41	413	11.30	517	10.19	391	32
33	5	33	6.2	7.67	79	14.04	460	10.35	488	10.76	376	33
35	5	16.5	25	6.30	129	9.74	324	12.42	469	9.55	328	35
36	5	8.2	25	9.09	295	13.10	500	10.75	429	10.92	418	36
38	12	0.5	5.7	....	...	17.39	348	6.48	256	5.22	220	38
39	..	..	..	....	...	7.40	254	7.43	198	6.20	204	39
Total				146.27	2,746	287.00	9,189	265.07	11,229	226.62	7,870	
Average increase per acre				6.36	119	11.04	353	10.19	432	8.72	303	

*Estimates.

TABLE XXI. Oats in 5 year rotation at Strongsville. Average annual yield per acre by periods.

Plot No.	Fertilizers in rounds per acre			5 years 1896-00		5 years 1901-05		5 years 1906-10		16 years 1896-1911		Pl't No.
	Acid phosphate	Muriate of potash	Nitrate of soda	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	
1	...	..	...	29.39	1,176	35.59	1,508	32 62	1,158	33.09	1,298	1
2	80	..	...	38.95	1,475	47.00	1,909	39.18	1,340	42.41	1,602	2
3	...	80	...	30.08	1,099	36.15	1,585	31.83	1,051	33.38	1,280	3
4	...	..	...	27.87	978	36.70	1,485	31.34	1,024	32.81	1,201	4
5	...	..	160	29.03	1,116	37.09	1,593	31.97	1,041	33.68	1,297	5
6	80	..	260	43.51	1,538	53.56	2,194	39.58	1,429	46.25	1,766	6
7	...	..	...	31.19	1,132	37.44	1,654	32.79	1,157	34.73	1,370	7
7	80	80	...	43.03	1,572	49.72	2,191	43.09	1,647	46 02	1,857	8
9	...	80	160	34.73	1,388	42.69	1,954	38.65	1,393	39.44	1,608	9
10	...	..	...	33.73	1,266	42.97	1,774	36.43	1,360	37.84	1,468	10
11	80	80	160	46.86	1,863	59.39	2,442	44.40	1,737	50.51	2,041	11
12	80	80	240	47.67	1,907	58.65	2,147	43.18	1,578	50.07	1,904	12
13	...	..	...	34.92	1,422	41.67	1,726	34.99	1,269	37.52	1,491	13
14	[1]...	..	...	40.06	1,553	46.55	1,870	37.29	1,362	41.42	1,610	14
15	[2]...	..	...	34.09	1,318	39.47	1,681	34.47	1,255	36.39	1,441	15
16	...	..	...	33.59	1,231	39.89	1,607	33.62	1,262	35.19	1,353	16
17	160	80	80	45.19	1,771	58.13	2,213	44.16	1,679	49.82	1,935	17
18	[3]...	..	...	37.80	1,392	47.64	2,039	41.47	1,652	42.78	1,726	18
19	...	..	...	29.93	1,076	39.80	1,572	35.50	1,288	35.42	1,332	19
20	[4]...	..	...	35.14	1,360	45.53	1,939	40.93	1,578	40.86	1,654	20
21	145	175	[5]...	45.40	1,927	59.79	2,517	45.78	1,829	50.78	2,129	21
22	...	..	...	34.22	1,407	44.11	1,934	37.59	1,445	39.28	1,638	22
23	150	80	[6]...	48.03	2,167	57.97	2,367	47.20	1,875	51.68	2,205	23
24	160	80	[7]...	47.46	2,105	58.67	2,316	46.96	1,911	51.66	2,190	24
25	...	..	...	31.97	1,395	40.37	1,579	36.58	1,385	37 33	1,538	25
26	[8]...	80	150	44.47	1,756	54.30	2,115	43.94	1,732	48.52	1,940	26
27	[9]...	80	160	44.43	1,809	55 69	2,155	43.86	1,686	48.88	1,817	27
28	...	..	...	30.62	1,127	38.72	1,474	34.18	1,155	35.31	1,307	28
26	[10]...	80	160	43.61	1,703	54.03	2,137	41.53	1,523	45.25	1,836	29
30	[11]...	80	[11]...	42.67	1,638	58 50	2,100	42.73	1,605	48.49	1,830	30
31	...	..	...	29.28	1,200	35.89	1,497	34.06	1,224	34.29	1,369	31
32	80	80	80	42.41	1,692	52.53	2,052	43.00	1,632	46.87	1,857	32
33	80	80	40	41.22	1.726	50.33	1,983	42.39	1,593	45.77	1,834	33
34	...	..	...	28.00	1,114	35.48	1,463	32.23	1,212	32.90	1,317	34
35	80	40	160	41.92	1,714	54.18	2,125	42.50	1,824	47.04	1,574	35
36	80	20	160	41.70	1,608	52.64	2,072	40.36	1,798	45.75	1,875	36
37	...	..	...	28.39	1,146	39.43	1,538	32.95	1,375	34.32	1,397	37
38	[12]...	..	...	30.12	1,242	40.92	1,587	33.31	1,412	35.37	1,447	38
39	[13]...	..	...	30.01	1,131	39.14	1,527	32.86	1,492	35.03	1,449	39
30	...	..	...	28.14	1,085	35.22	1,417	30.17	1,128	31.62	1,247	40
Unfertilized yield				30.80	1,197	38.80	1,588	33 93	1,240	35.11	1,380	
Fertilized yield				41.28	1,639	50.84	2,048	40.64	1,561	44.36	1,777	

[1]Fertilized on corn and wheat only. [2]Fertilized on wheat only. [3]Barnyard manure, 8 tons each on corn and wheat. [4]Barnyard manure, 4 tons each on corn and wheat. [5]Linseed oilmeal, 230 lbs. [6]Dried blood, 100 lbs. [7]Sulphate of ammonia, 60 lbs. [8]Bonemeal, 35 lbs. [9]Dissolved bonemeal, 16 percent, 140 lbs. [10]Basic slag, 17 percent, 75 lbs. [11]Tankage, carrying phosphorus and nitrogen equivalent to applications on Plots 17, 21, 23 and 24. [12]Fertilized on wheat only. [13]Manured on wheat only.

TABLE XXII. Oats in 5-year rotation at Strongsville. Average annual increase per acre by periods

Plot No.	Fertilizing elements per acre			5 years 1896-00		5 years 1901-05		5 years 1906-10		16 years 1896-1911		Pl't No.
	Phosphorus Lbs.	Potassium Lbs.	Nitrogen Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	
2	5	..	..	10.07	365	11.04	409	6.99	227	9.41	336	2
3	..	33	..	1.70	55	—0.18	92	.06	—15	.48	47	3
5	..	..	25	0.05	87	0.15	53	.14	—28	.24	40	5
6	5	..	25	13.43	458	16.37	597	7.27	316	12.16	453	6
8	5	33	..	10.97	395	10.44	497	9.08	422	10.25	455	8
9	..	33	25	1.85	167	1.56	219	3.44	100	2.63	173	9
11	5	33	25	12.72	545	16.86	684	8.45	407	12.77	565	11
12	5	33	37	13.14	537	16.55	405	7.72	278	12.44	420	12
14	..	..	..	5.59	194	5.47	183	2.76	95	4.67	164	14
15	..	..	..	....	...	—1.02	34	.40	—9	.65	56	15
17	10	33	12.5	12.82	592	18.27	617	9.91	409	14.56	582	17
18	..	..	..	6.64	265	7.81	455	6.60	372	7.44	387	18
20		..	..	3.78	174	4.29	246	4.74	238	4.00	219	20
21	10	33	12.5	12.61	630	17.12	703	8.89	439	12.79	592	21
23	10	33	12.5	14.56	764	15.10	551	9.94	451	13.05	600	23
24	10	33	12.5	14.75	706	17.05	619	10.04	506	13.68	619	24
26	5	33	25	12.95	450	14.48	572	8.16	423	11.86	479	26
27	5	33	25	13.37	592	16.43	547	8.87	454	12.90	568	27
29	5	33	25	13.44	552	16.26	655	7.39	345	12.16	508	29
30	10	33	12.5	12.94	463	21.67	628	8.63	404	13.97	482	30
32	5	33	12.5	13.55	521	16.77	566	9.55	412	13.04	505	32
33	5	33	6.2	12.79	583	14.71	509	9.55	377	12.41	499	33
35	5	16.5	25	13.79	590	17.38	637	10.02	557	13.67	605	35
36	5	8.2	25	13 45	473	14.52	559	7.65	457	11.90	505	36
38	..	..	..	....	...	2.89	90	1.09	118	1.95	101	38
39	..	..	..	....	...	2.44	70	1.76	282	2.55	152	39
Total 24 plots........				240.96	10,158	288.96	110.37	166.25	7,637	233.13	9,849	
Average increase per acre.....				10.48	442	12.04	4.60	6.93	318	9.71	410	

TABLE XXIII: Wheat in 5-year rotation at Strongsville. Average annual yield per acre by periods.

Plot No.	Fertilizers in pounds per acre				5 years, 1897-1901		5 years, 1902-1906		5 years, 1907-1911		15 years, 1897-1911		Plot No.
	Acid phosphate	Muriate of potash	Dried blood	Nitrate of soda	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	
1	...	...	..	...	3.52	320	4.65	443	9.31	1,185	5.82	650	1
2	160	...	..	...	9.33	1,061	13.72	1,167	16.28	1,729	13.11	1,319	2
3	...	100	..	...	3.76	335	5.32	413	8.68	1,025	5.92	591	3
4	...	...	..	...	4.42	453	5.56	469	10.30	1,128	6.76	683	4
5	...	...	50	120	4.16	416	5.57	446	9.89	1,174	6.54	679	5
6	160	...	50	120	12.51	1,292	17.43	1,474	20.68	2,173	16.87	1,646	6
7	...	...	..	...	4.38	446	6.39	512	9.77	1,199	6.85	719	7
8	160	100	..	...	10.66	1,031	16.71	1,302	19.52	1,840	15.63	1,391	8
9	..	100	50	120	6.00	647	9.15	819	13.67	1,505	9.61	990	9
10	...	...	..	...	4.52	469	7.83	670	13.50	1,354	8.61	831	10
11	160	100	50	120	13.54	1,301	19.30	1,785	22.52	2,356	18.45	1,814	11
12	160	100	50	200	16.51	1,733	21.71	1,904	23.97	2,489	20.73	2,042	12
13	...	...	..	...	4.82	487	7.79	625	12.41	1,403	8.34	838	13
14	[1]160	100	50	120	15.25	1,487	19.22	1,744	21.48	2,213	18.65	1,815	14
15	[2]160	100	50	120	13.75	1,331	17.76	1,536	19.70	2,068	17.07	1,645	15
16	...	...	..	...	5.57	523	7.61	573	12.46	1,288	8.55	795	16
17	160	100	25	60	10.36	972	18.97	1,568	21.90	2,144	17.07	1,561	17
18	[3]...	...	..	...	12.57	1,262	15.88	1,476	20.79	2,248	16.41	1,662	18
19	...	...	..	...	3.17	246	6.03	515	11.33	1,227	6.84	662	19
20	[4]...	...	..	...	8.94	863	11.73	1,107	17.59	1,924	12.75	1,298	20
21	145	95	..	[5]...	11.66	1,149	20.00	1,058	22.49	2,444	18.05	1,750	21
22	...	...	..	...	5.22	500	8.93	736	12.92	1,424	9.03	887	22
23	150	100	100	...	12.78	1,317	20.07	1,685	20.32	2,193	17.73	1,732	23
24	160	100	25	[6]...	13.36	1,382	20.36	1,680	20.82	2,205	18.18	1,756	24
25	...	...	..	...	4.78	485	7.91	580	11.96	1,380	8.21	815	25
26	[7]...	100	20	120	14.11	1,404	21.86	1,740	20.58	2,153	18.85	1,766	26
27	[8]...	100	50	120	12.73	1,232	20.70	1,744	19.66	2,152	17.70	1,709	27
28	...	...	..	...	5.07	502	7.82	581	12.12	1,367	8.34	817	28
29	[9]...	100	50	120	15.13	1,496	19.83	1,602	21.10	2,288	18.69	1,795	29
30	[10]...	100	..	...	13.06	1,298	21.50	1,716	21.22	2,208	18.60	1,741	30
31	...	...	..	...	4.04	405	6.66	505	12.72	1,360	7.81	757	31
32	160	100	25	60	12.71	1,251	17.57	1,453	20.17	2,052	16.81	1,585	32
33	160	100	15	30	11.41	986	16.90	1,362	18.94	2,015	15.75	1,455	33
34	...	...	..	...	4.45	441	5.98	486	11.57	1,256	7.33	728	34
35	160	50	50	120	13.13	1,249	17.57	1,525	21.69	2,256	17.46	1,677	35
36	160	25	50	120	13.73	1,347	18.95	1,544	20.31	2,055	17.67	1.649	36
37	...	...	..	...	4.34	400	6.19	462	9.86	1,150	6.80	671	37
38	100	10	[11]..	...	12.39	1,225	15.87	1,311	17.18	1,784	15.15	1,440	38
39	[12]...	...	..	...	9.89	943	13.60	1,321	19.42	2,164	14.30	1,476	39
40	...	...	..	...	4.77	426	5.28	420	9.74	1,115	6.60	654	40
Average unfertilized yield					4.50	436	6.74	542	11.47	1,278	7.57	752	
Average fertilized yield.......					11.54	1,149	16.65	1,418	19.25	2,037	15.91	1 538	

[1] Fertilized on corn and wheat only. [2] Fertilized on wheat only. [3] Barnyard manure, 8 tons each on corn and wheat. [4] Barnyard manure, 4 tons each on corn and wheat. [5] Linseed oilmeal, 230 lbs. [6] Sulphate of ammonia, 45 lbs. [7] Bonemeal, 110 lbs. [8] Dissolved boneblade, 16%, 140 lbs. [9] Basic slag, 17%, 130 lbs. [10] Tankage, carrying phosphorus and nitrogen equivalent to applications on Plots 17, 21, 23 and 24. [11] Tankage, 7-30, 100 lbs. [12] Barnyard manure, 16 tons.

TABLE XXIV: Wheat in 5-year rotation at Strongsville. Average annual increase per acre by periods.

Plot No.	Fertilizing elements per acre			5 years, 1897-1901		5 years 1902-1906		5 years 1907-1911		15 years 1897-1911		Pl't No.
	Phosphorus Lbs.	Potassium Lbs.	Nitrogen Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.	
2	10	..	..	5.51	696	8.77	715	6.64	550	6.98	654	2
3	..	41	..	—0.36	—73	0.06	—47	—1.29	—125	—.53	—82	3
5	..	..	25	—0.25	—34	—0.23	—38	—.30	23	—.26	—16	5
6	10	..	25	8.11	845	11.32	976	10.80	997	10.05	939	6
8	10	41	..	6.23	578	9.84	737	8.51	589	8.19	635	8
9	..	41	25	1.53	186	1 80	201	1.40	203	1.57	197	9
11	10	41	25	8.92	826	11.49	1,129	9.37	986	9.93	981	11
12	10	41	38	11.79	1,252	13.91	1,264	11.20	1,103	12.30	1,206	12
14	10	41	25	10.19	987	11.49	1,137	9.05	849	10.24	991	14
15	10	41	25	8.45	818	10.09	945	7.25	742	8.60	835	15
17	10	41	12.5	5.61	540	11.89	1,014	9.81	876	9.10	811	17
18	40*	120*	150*	8.61	923	9.33	942	9.08	1,001	9.01	955	18
20	20*	60*	75*	5.09	532	4.74	518	5.71	632	5.18	561	20
21	10	41	12.5	7.12	733	12.04	996	10.10	1,085	9.75	938	21
23	10	41	12.5	7.71	822	11.48	1,001	7.72	783	8.97	868	23
24	10	41	12.5	8.43	893	12.11	1,049	8.54	810	9.69	917	24
26	10	41	25	9.23	914	13.98	1,160	8.57	778	10.60	951	26
27	10	41	25	7.75	736	12.85	1,163	7.60	781	9.40	893	27
29	10	41	25	10.40	1,026	12.39	1,046	8.78	923	10.53	998	29
30	10	41	12.5	8.67	861	14.45	1,185	8.70	846	10.61	964	30
32	10	41	12.5	8.53	834	11.12	954	7.83	727	9.17	838	32
33	10	41	6.2	7.10	557	10.69	870	7.00	724	8.26	718	33
35	10	20.5	25	8.72	822	11.52	1,047	10.69	1,036	10.31	968	35
36	10	10.2	25	9.36	933	12.84	1,074	9.88	870	10.69	959	36
38	12.3	4	7	7.91	816	9.95	862	7.36	646	8.42	775	38
39	40*	120*	150*	5.26	525	8.02	886	9.64	1,037	7.64	814	39
Total..........................				185.62	18,542	257.64	22,786	203.22	19,722	214.40	20,268	
Average increase per acre.....				7.14	713	9.91	876	7.78	759	8.25	780	

*Estimates.

TABLE XXI: Clover in 5-year rotation at Strongsville. Average annual yield and increase of hay by periods.

Plot No.	Fertilizing elements per acre on previous crops of rotation			Yield per acre				Increase per acre				Pl't No.
	Phosphorus Lbs.	Potassium Lbs.	Nitrogen Lbs.	5 yrs. 1897-01 Lbs.	5 yrs. 1902-06 Lbs.	5 yrs. 1907-11 Lbs.	15 yrs. 1897-11 Lbs.	5 yrs. 1897-01 Lbs.	5 yrs. 1902-06 Lbs.	5 yrs. 1907-11 Lbs.	15 yrs. 1897-11 Lbs.	
1	..	...	..	1,388	1,125	2,274	1,596	...	...	...	...	1
2	20	...	..	2,188	1,989	3,170	2,449	870	939	851	887	2
3	..	107	..	1,303	1,121	2,424	1,615	54	146	60	87	3
4	..	...	..	1,178	900	2,408	1,495	...	...	...	...	4
5	..	...	75	1,516	1,080	2,867	1,821	195	114	822	210	5
6	20	...	75	2,236	1,817	3,421	2,491	771	786	738	764	6
7	..	...	..	1,608	1,098	2,820	1,842	...	...	...	...	7
8	20	107	.	2,296	1,806	3,339	2,500	703	639	648	663	8
9	..	107	75	1,792	1,261	3,185	2,079	213	23	502	247	9
10	..	...	..	1,564	1,306	2,613	1,828	...	...	...	...	10
11	20	107	75	2,518	1,928	3,775	2,740	916	654	1,123	897	11
12	20	107	114	2,332	1,980	3,668	2,660	692	789	977	803	12
13	..	...	..	1,678	1,209	2,729	1,872	...	...	...	...	13
14	15	74	50	2,452	1,834	3,743	2,676	795	623	985	801	14
15	10	41	25	2,146	1,698	3,533	2,459	511	484	744	580	15
16	..	...	..	1,614	1,216	2,819	1,883	...	...	...	...	16
17	30	107	37	2,336	1,978	3,979	2,764	781	785	1,053	873	17
18	40*	120*	150*	2,420	1,766	4,037	2,741	922	597	1,004	841	18
19	..	...	..	1,138	1,146	3,141	1,908	...	...	...	...	19
20	20*	60*	75	2,176	1,790	3,919	2,628	667	551	682	633	20
21	30	107	37	2,584	2,188	3,669	2,815	1,003	867	342	734	21
22	..	...	..	1,652	1,244	3,431	2,169	...	...	...	...	22
23	30	107	37	2,686	1,968	3,787	2,811	1,040	591	522	717	23
24	30	107	37	2,480	1,998	3,953	2,810	839	687	849	792	24
25	..	...	..	1,636	1,254	2,940	1,943	...	...	...	...	25
26	20	107	75	2,602	2,127	3,936	2,888	1,035	924	1,062	1,007	26
27	20	107	75	2,200	1,800	3,717	2,572	703	648	908	753	27
27	..	...	..	1,428	1,101	2,744	1,758	...	...	...	...	28
29	20	107	75	2,372	1,736	3,780	2,629	961	646	992	866	29
30	30	107	37	2,600	2,220	3,941	2,920	1,207	1,141	1,109	1,152	30
31	..	...	..	1,376	1,068	2,876	1,773	...	...	...	...	31
32	20	107	37	2,392	1,824	3,782	2,666	1,034	764	629	909	32
33	20	107	19	2,548	1,912	3,590	2,683	1,208	856	780	941	33
34	..	...	..	1,322	1,048	2,808	1,726	...	...	...	...	34
35	20	53	37	2,282	1,830	3,918	2,677	885	762	950	866	35
36	20	26	37	2,500	2,136	3,844	2,827	1,029	1,048	718	932	36
37	..	...	..	1,546	1,108	3,285	1,980	...	...	...	...	37
38	12.3	4	7	2,420	1,869	3,517	2,602	918	752	397	689	38
39	40*	120*	150*	2,148	1,869	4,387	2,801	690	744	1,433	955	39
40	..	...	..	1,414	1,134	2,789	1,779	...	...	...	...	40
Average unfertilized yield				1,467	1,140	2,832	1,825	794	673	798	754	
Average fertilized yield.......				2,289	1,827	3,651	2,589					

*Estimates.

TABLE XXVI: Timothy in 5-year rotation at Strongsville. Average annual yield and increase of hay by periods.

Plot No.	Fertilizing elements per acre on previous crops of rotation: Nitrogen Lbs.	Phosphorus Lbs.	Potassium Lbs.	Yield per acre: 5 yrs. 1898-02 Lbs.	5 yrs. 1903-07 Lbs.	5 yrs. 1908-12 Lbs.	15 yrs. 1898-12 Lbs.	Increase per acre: 5 yrs. 1898-02 Lbs.	5 yrs. 1903-08 Lbs.	5 yrs. 1908-12 Lbs.	15 yrs. 1898-12 Lbs.	Plot No.
1	..	...	..	1,676	220	2,227	1,374	...	...	...	...	1
2	20	...	..	1,660	378	2,428	1,489	132	168	190	164	2
3	..	107	..	1,352	210	1,997	1,186	—28	11	—249	—89	3
4	..	...	..	1,232	189	2,257	1,228	...	...	...	...	4
5	..	...	75	1,196	254	2,466	1,305	—33	45	124	45	5
6	20	...	75	1,374	337	2,942	1,561	147	108	514	256	6
7	..	...	..	1,224	249	2,513	1,329	...	...	...	...	7
8	20	107	..	1,752	302	2,898	1,651	363	31	425	273	8
9	..	107	75	1,540	277	2,514	1,444	—15	—16	82	17	9
10	..	...	..	1,720	315	2,391	1,475	...	...	...	...	10
11	20	107	75	2,072	344	2,905	1,774	393	15	499	302	11
12	20	107	114	1,912	343	2,740	1,668	275	—1	328	201	12
13	..	...	..	1,596	358	2,437	1,464	...	...	...	...	13
14	15	74	50	1,856	348	2,743	1,649	299	27	276	201	14
15	10	41	25	1,582	376	2,570	1,509	63	93	74	77	15
16	..	...	..	1,480	246	2,526	1,417	...	...	...	...	16
17	30	107	37	1,716	310	3,017	1,681	260	61	460	260	17
18	40*	120*	150*	1,808	337	3,099	1,748	376	84	512	324	18
19	..	...	..	1,408	256	2,618	1,427	...	...	...	...	19
20	20*	60*	75*	1,828	431	2,784	1,681	361	176	198	245	20
21	30	107	37	1,912	448	2,824	1,728	387	194	271	284	21
22	..	...	..	1,584	253	2,521	1,453	...	...	...	...	22
23	30	107	37	1,920	356	3,033	1,770	391	75	529	332	23
24	30	107	37	1,844	368	2,990	1,734	369	59	504	311	24
25	..	...	..	1,420	337	2,469	1,409	...	...	...	...	25
26	20	107	75	1,636	326	3,006	1,656	283	7	325	286	26
27	20	107	75	1,388	320	2,993	1,434	105	20	575	100	27
28	..	...	..	1,216	282	2,392	1,297	...	...	...	...	28
29	20	107	75	1,556	365	2,768	1,563	343	63	364	257	29
30	30	107	37	1,768	505	2,935	1,736	557	182	520	420	30
31	..	...	..	1,208	343	2,427	1,326	...	...	...	...	31
32	20	107	37	1,488	400	2,709	1,532	285	76	330	230	32
33	20	107	19	1,644	420	2,647	1,570	444	114	319	292	33
34	..	...	..	1,196	287	2,279	1,254	...	...	...	...	34
36	20	53	37	1,612	380	2,571	1,521	394	84	332	270	35
35	20	26	37	1,496	398	2,704	1,533	256	92	505	286	36
37	..	...	..	1,262	315	2,159	1,245	...	...	...	...	37
38	12.3	4	7	1,554	335	2,755	1,548	352	28	533	304	38
39	40*	120*	150*	1,364	378	3,325	1,689	222	78	1,041	447	39
40	..	...	..	1,082	292	2,347	1,240	..	...	...	...	40
Average unfertilized yield				1,379	282	2,397	1,290	268	72	368	235	
Average fertilized yield				1,647	348	2,776	1,593					

* Estimates.

SOIL INVESTIGATIONS

OHIO
Agricultural Experiment Station

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[1] In cooperation with Bureau of Plant Industry, U. S. Department of Agriculture.
[2] In cooperation with Boys' Industrial School. [3] In cooperation with Ohio State Reformatory

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SOIL INVESTIGATIONS

COMPOSITION OF CALCAREOUS AND NON-CALCAREOUS SOILS (WITH SPECIAL REFERENCE TO PHOSPHORUS SUPPLY)

J. W. AMES AND E. W. GAITHER

The study of soil phosphorus is included as a part of the soil investigations being conducted at this Station. For the purpose of obtaining information concerning differences in composition of calcareous and non-calcareous soils of different types, a chemical examination of a number of soils from sandstone, limestone and shale formations has been made. The work was undertaken with the object in view of establishing a basis for investigation pertaining to the deficiency, availability and combination of the phosphorus supply in soils having widely differing characteristics. Considerable data have been secured showing the relation between the calcium carbonate content and soil reaction, which is considered of importance in measuring the availability of the phosphorus supply.

TOTAL ANALYSES

As pointed out by Merrill,* for a long period the fertility of soils was thought to be dependent largely upon their chemical composition. A vast amount of data was obtained by determining the portion of the several soil constituents soluble in strong acids. This has proven in the light of later knowledge to be of questionable value. By this method there is left undetermined a large proportion of the elements, aside from silica, concerning which it may be highly important to have complete information.

The determination of the total amounts of the elements present, not only for the surface soils, but for the various sub-strata as well, is of importance in connection with agricultural geology.

*Rocks, Rock Weathering and Soils.

In the chemical work on soils carried on at this Station the practice has been followed of determining the total amounts of the elements present, and the proportion of these soluble in fifth normal nitric acid, including iron and aluminum. For some soils the relative proportion of these two elements, compared with the calcium carbonate and phosphorus content, will have a bearing on the phosphorus availability.

The methods of analysis used are given in detail in addenda, page 503.

LIMESTONE AND SANDSTONE SOILS

The State is divided into two principal geological sections or divisions, designated as glaciated and unglaciated. The former lies over the northern and western sections of the State, while the section free from, or only slightly modified by glacial action extends over the eastern and southern portions; the division between these two is represented on the map shown on page 452. The soils studied lie mostly in the glaciated area; Jefferson, Washington, and Meigs counties being the only counties in the unglaciated section from which samples were obtained. The soil forming material over different parts of the area affected by glacial action was of different character. Soils east of a line extending north and south through the center of the State are largely derived from sandstones and shales, and those west of this line from limestone. The chief distinction between these two classes of soil which would be expected from their origin is in their content of calcium carbonate. In many instances the amount of calcium carbonate found in the surface soils gives only a slight indication of their being derived from limestone. The extent to which the decomposition and removal of soil forming materials have proceeded is indicated by chemical analyses of the different soil strata. The agencies through which these changes take place may exert a more marked influence upon the soil composition than does the material from which the soil was formed.

The terms "limestone soil" and "calcareous soil" are frequently used with reference to the presence of calcium carbonate. A limestone soil is not necessarily a calcareous soil, for many of the soils formed from limestone have had the calcium carbonate, at one time present, removed from the depth of soil which furnishes the medium for plant growth. In the case of many of the soils from limestone areas in the western part of the State there is a marked difference between the surface six inches of soil and the depth from six inches to three feet, as regards the amount of calcium and magnesium carbonates present.

Table I points out the differences found between soils from the eastern and western parts of the State. This table is a summary of results for calcium carbonate; total and fifth normal nitric acid-soluble calcium, magnesium and phosphorus. The soils from the western section, overlying limestone, are divided into two groups, calcareous and non-calcareous. The more extended area, represented by samples from the western part of the State, compared with that from the eastern portion, probably does not admit of more than an approximate comparison being made. Nevertheless, the larger amounts of calcium carbonate found in soils from the western portion, and the proportions of total and fifth normal nitric acid-soluble calcium, even in cases where no carbonates were found, are of interest.

TABLE I. Soils from eastern and western sections of the State compared. Results expressed as pounds per 2,000,000 pounds of soil.

	Depth	$CaCO_3$*	Calcium		Magnesium		Phosphorus	
			Total	N-5 HNO_3 soluble	Total	N-5 HNO_3 soluble	Total	N-5 HNO_3 soluble
Eastern	0-6 in.	0	6,850	1,652	8,856	286	986	23.1
"	6-36 in.	0	6,814	1,576	11,324	532	645	31.0
Western, No $CaCO_3$	0-6 in.	0	10,183	2,484	8,890	509	913	60.0
" " "	6-36 in.	0	9,300	2,482	13,614	870	702	19.8
Western, Containing $CaCO_3$	0-6 in.	6,025	16,221	7,680	9,830	1,284	1,310	144.0
Western, Containing $CaCO_3$	6-36 in.	42,800	25,188	16,590	16,182	5,401	904	166.0

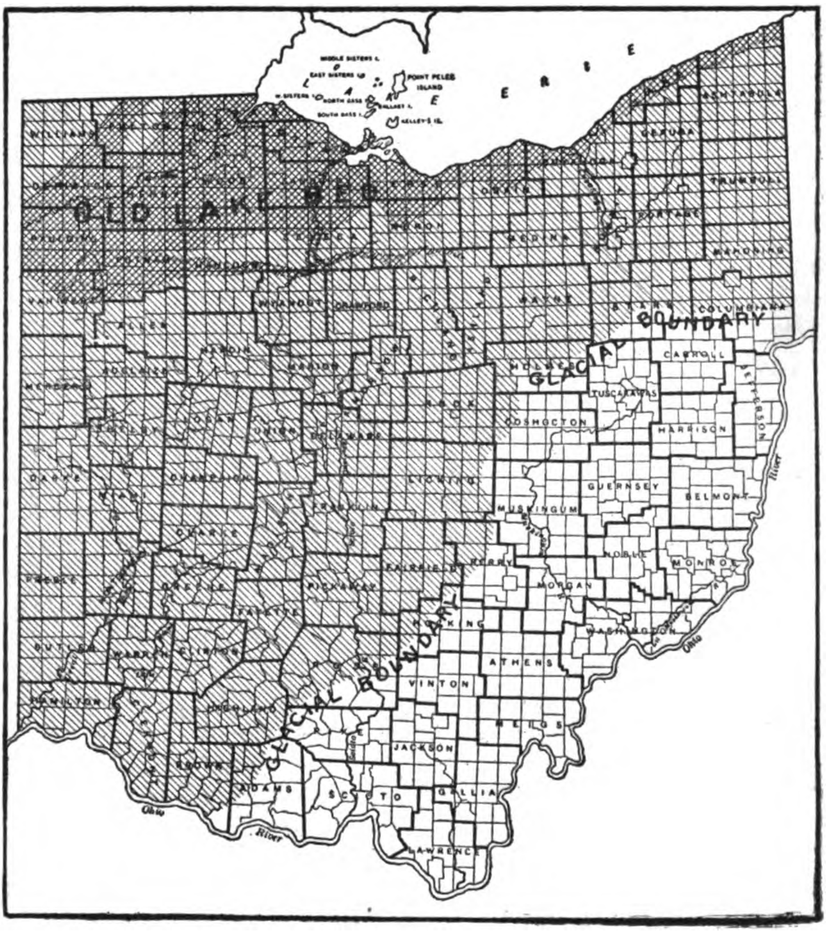
*Calcium carbonate.

The amounts of calcium, both total and fifth normal nitric acid-soluble, found in these instances, indicate that a portion of the calcium which at some time in the past existed as calcium carbonate, now exists in other combinations than the basic carbonate of calcium, by reason of chemical changes taking place between the calcium carbonate and the organic and inorganic constituents. It is probable that, where a considerable amount of organic material existed in the soil, acidity was developed, which was neutralized by the carbonates of calcium and magnesium, forming organic combinations with these elements. Since these organic compounds are not readily soluble in carbonated water, they remain in the soil after the excess of natural carbonates is decomposed and leached out. Calcareous soils generally support a luxuriant natural growth of vegetation, which returned to the soil furnishes abundant organic material to bring about this condition, thus giving rise to the accumulation of calcium in the surface strata, while the subsoil may contain less of this element.

Bacteria acting on this supply of calcium in organic combination may form calcium carbonates, which will tend to maintain a neutral reaction in soils even though the amount of calcium carbonate can not be measured by a chemical analysis.

Experiments, which are indicative of the change from organic calcium salts to calcium carbonate, are reported by the Rothamsted Experiment Station.*

Table II, on page 453 and following, gives the fertility constituents and reaction of soils grouped according to the counties from which the soils analyzed were secured. The location and description of the soils studied are shown in Table III.



Map of Ohio showing glaciated area.

*C. T. Gimingham, Jour. Agr. Science, Vol. IV, part 2, pp. 145.

TABLE II. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium Total	Magnesium Soluble*	Calcium Total	Calcium Soluble*	Phosphorus Total	Phosphorus Soluble*	Potassium	Nitrogen	Humus	$CaCO_3$† in soil	Reaction to litmus paper
4651	0-6	Ashtabula	Gravelly loam	8,444	112	9,290	1,210	1,620	88	25,144	2,314	31,200	0	Acid
4648	0-6	"	"	10,742	192	5,472	1,280	1,008	6	34,492	3,360	31,400	0	"
4649	6-36	"	"	17,370	612	4,512	1,392	622	2	51,388	1,380	......	0	"
4650	0-6	"	"	9,188	184	8,256	974	1,132	4	31,912	2,844	30,400	0	Sl. acid
4652	0-6	"	Gravel	7,854	82	9,216	896	1,326	24	26,240	2,480	35,800	0	Acid
4654	0-6	"	"	8,510	102	6,432	788	1,930	170	26,564	3,626	41,800	0	"
4658	0-6	"	Sandy loam	6,980	70	11,232	164	1,150	50	22,632	3,314	38,600	0	"
4659	6-36	"	"	8,686	90	13,728	158	556	30	25,144	1,040	......	0	"
4660	0-6	"	"	12,204	120	17,760	890	1,116	232	22,952	2,254	27,000	100	Sl. acid
4661	0-6	"	"	10,598	52	10,752	262	2,200	120	22,696	3,070	38 600	0	Acid
4662	0-6	"	"	8,268	292	7,006	3,916	1,034	48	25,726	4,090	42,400	0	"
4644	0-6	"	Volusia loam	11,812	272	6,096	2,582	988	6	39,458	4,280	40,400	0	"
4645	6-36	"	"	17,478	840	5,088	2,214	596	4	49,386	1,340	......	0	"
4646	0-6	"	"	9,690	236	5,380	2,454	746	6	31,590	3,900	34,200	0	"
4647	0-6	"	"	9,800	122	3,744	560	964	12	29,916	2,814	27,600	0	"
4655	0-6	"	Clay	7,394	358	5,100	1,634	1,008	88	34,428	6,380	70,800	0	"
4656	6-36	"	"	15,182	970	8,100	5,346	834	190	45,772	1,350	......	400	Alkaline
4657	0-6	"	"	9,078	556	6,240	2,734	1,318	8	39,328	5,050	48,000	0	Acid
4733	0-6	Allen	Silt loam	8,338	798	17,922	6,156	1,408	28	37,588	5,060	49,800	0	Sl. acid
4730	0-6	"	Clay loam	10,854	1,366	14,914	5,166	1,336	22	39,132	4,420	38,600	2,200	Alkaline
4731	6-36	"	"	26,030	7,874	46,652	33,508	964	98	48,100	1,694	......	92,200	"
4732	0-6	"	"	9,132	742	11,906	3,632	950	24	43,072	5,674	35,800	0	Sl. acid
10746	0-6	Auglaize	Silt loam	11,310	496	9,644	3,040	854	14	37,396	3,074	......	0	Sl. acid
10744	0-6	"	Blk. clay loam	17,172	2,188	21,254	9,900	1,374	168	36,624	6,650	......	.	....
10745	0-6	"	"	19,076	1,784	20,566	11,050	2,330	302	44,100	7,324	......	.	....
5286	0-6	Brown	Silt loam	11,400	392	9,828	1,752	1,206	14	26,370	2,930	36,000	.	....
5287	6-36	"	"	14,624	450	7,984	672	690	6	29,208	924	......	0	Acid
5288	0-6	"	"	10,498	526	12,896	1,350	890	14	25,016	2,474	37,000	0	"
5289	6-36	"	"	10,464	474	10,066	1,398	582	8	24,372	.....	......	.	....
5294	0-6	"	"	6 234	280	3,958	1,650	1,234	8	25,792	2 790	36 200	0	Acid

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium Total	Magnesium Soluble*	Calcium Total	Calcium Soluble*	Phosphorus Total	Phosphorus Soluble*	Potassium	Nitrogen	Humus	CaCO₃ † in soil	Reaction to litmus paper
10751	0-6	Butler	Sandy loam	55,584	33,732	131,902	108,532	1,392	176	29,660	1,894	19,000	403,000	Str. alk'line
4565	0-6	"	Silt loam	8,120	662	9,698	2,714	1,158	14	37,008	2,714	48,200	0	Sl. acid
4566	6-36	"	"	36,528	20,058	81,520	70,024	1,760	456	39,584	1,230	......	.	....
4567	0-6	"	"	7,874	778	10,802	3,044	734	14	34,172	2,530	27,600	0	Sl. acid
4568	6-36	"	"	32,660	10,478	38,968	19,400	1,486	138	35,588	1,704	......	.	....
10750	0-6	"	Clay loam	7,328	1,052	10,924	4,056	1,694	132	55,848	2,674	......	2,400	Sl. alkaline
4744	0-6	Clarke	Silt loam	6,432	474	8,256	2,498	930	20	37,008	2,170	26,200	600	Alkaline
4745	6-36	"	"	11,460	936	7,248	1,888	822	12	39,328	1,044	......	0	Sl. acid
4746	0-6	"	"	6,258	552	7,776	2,278	910	26	37,458	2,644	28,600	300	Alkaline
4747	0-6	"	"	9,800	352	8,660	1,752	818	18	38,426	2,304	19,400	150	Sl. alkaline
4748	6-36	"	"	19,360	3,448	15,842	8,872	1,042	28	45,712	1,380	.....	25,100	Alkaline
4749	0-6	"	"	8,612	1,526	14,116	4,866	1,360	28	37,394	3,034	22,600	3,100	Sl. alkaline
4750	6-36	"	"	29,202	13,088	35,108	23,618	1,114	22	38,170	1,624	.....	91,400	"
4751	0-6	"	"	6,588	752	11,968	3,004	790	16	36,106	2,514	19,600	2,300	Alkaline
4741	0-6	"	Bl'k, clay loam	13,300	3,828	26,400	21,200	2,188	108	26,240	13,250	129,600	2,300	Alkaline
4742	6-36	"	"	17,150	5,120	20,928	12,400	646	264	36,362	1,940	.....	16,600	"
4743	0-6	"	"	17,346	9,626	49,344	40,800	2,586	320	30,174	16,644	131,200	69,200	"
4665	0-6	Cuyahoga	Stony loam	6,748	252	5,010	1,202	580	8	31,720	2,520	26,800	0	Acid
4666	6-36	"	"	8,288	576	4,718	1,272	542	2	42,134	1,064	......	0	"
4667	0-6	"	"	5,864	192	5,690	448	900	8	29,980	2,460	23,800	100	Alkaline
4670	0-6	"	Gravelly loam	8,048	150	6,810	742	2,624	10	25,790	3,410	36,400	0	Acid
4668	0 6	"	Sandy loam	7,326	180	6,372	684	978	4	29,626	2,250	24,000	0	"
4669	6-36	"	"	9,328	530	6,032	742	602	6	35,588	780	......	0	"
4663	0-6	"	Clay loam	11,178	206	6,712	1,650	764	2	32,816	2,850	32,200	0	"
4664	6-36	"	"	11,822	918	6,908	2,652	642	8	48,096	1,344	......	0	"
4671	0-6	"	"	11,330	312	5,058	2,228	1,116	6	39,974	3,344	30,000	0	Sl. acid
4672	6-36	"	"	10,554	246	4,718	918	650	2	30,134	1,340	......	0	Acid
11381	0-6	"	Clay	8,356	578	5,100	2,162	880	12	41 320	3,600	40,000	0	Acid

*Soluble N-5 nitric acid †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	CaCO₃ † in soil	Reaction to litmus paper
	inches			Total	Soluble*	Total	Soluble*	Total	Soluble*					
5284	0-6	Clermont	Silt loam	11,892	316	11,056	2,300	1,356	14	30,880	186	28,000	0	Sl. acid
5285	6-36	"	"	15,694	762	9,152	1,488	640	6	33,784	944	......	0	"
5293	0-6	"	"	6,562	494	5,626	2,840	1,540	4	34,172	3,580	35,800	0	Acid
10756	0-6	"	"	6,104	232	6,788	1,420	856	2	28,758	2,380	......	0	"
4712	0-6	Defiance	Clay loam	10,644	1,322	12,310	4,762	770	28	39,522	3,154	39,200	2,450	Alkaline
4713	6-36	"	"	24,358	8,312	43,786	39,392	634	124	54,608	1,300	......	94,400	"
4714	0-6	"	"	11,604	3,456	19,168	12,854	962	48	36,942	4,244	24,600	26,000	"
4715	0-6	"	Clay	16,418	1,396	8,418	2,842	1,206	12	58,734	4,290	40,400	0	Sl. Acid
10769	0-6	Darke	Silt loam	11,944	1,816	17,016	8,962	2,136	108	35,782	.....	......	.	....
10770	0-6	"	"	12,512	1,740	18,984	8,300	1,192	110	37,588	.....	......	.	"
10771	0-6	"	"	12,514	1,488	17,410	6,450	1,434	118	36,492	4,670	......	600	Alkaline
10772	0-6	"	"	12,316	1,772	18,492	9,500	1,586	170	37,072	.....	......	500	"
10766	0-6	"	Clay loam	14,328	2,790	20,264	10,532	1,514	22	37,654	.....	......	.	....
10767	0-6	"	"	10,062	584	10,328	2,800	828	24	44,228	2,560	......	0	Sl. acid
10768	0-6	"	"	8,926	506	9,442	2,000	796	18	42,232	2,794	......	.	....
4734	0-6	Franklin	"	6,342	378	8,172	2,016	686	6	35,328	2,150	20,200	0	Sl. acid
4735	6-36	"	"	11,538	836	6,468	1,782	692	4	44,324	1,400	......	0	"
4736	0-6	"	"	6,080	468	8,074	3,030	786	10	33,510	2,874	25,600	0	"
5085	1-14	"	"	5,578	548	9,730	3,254	656	16	32,848	2,250	21,800	650	Alkaline
5088	14-24	"	"	8,826	1,316	8,074	3,774	422	26	36,490	1,264	......	0	Sl. alkaline
4737	0-6	"	Bl'k, clay loam	15,092	1,792	18,292	11,804	1,580	106	35,910	6,290	63,000	0	Neutral
4738	6-36	"	"	11,866	1,910	14,252	8,798	1,060	158	38,842	2,274	......	400	Sl. alkaline
4739	0-6	"	"	13,618	2,408	19,802	14,658	1,792	106	34,910	8,460	69,800	1,280	"
4740	0-6	"	"	6,432	288	8,736	3,880	1,750	200	30,304	2,840	25,400	200	Neutral
5087	1-14	"	Black clay	10,662	2,864	26,998	20,286	1,960	484	25,370	6,934	65,200	11,500	Alkaline
5086	14-24	"	"	44,844	35,960	102,066	96,004	1,034	416	25,982	.....	......	359,500	"

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	$CaCO_3$ † in soil	Reaction to litmus paper
	inches			Total	Soluble*	Total	Soluble*	Total	Soluble*					
14169	....	Fulton	Black sand	......	.....	28,360	15,860	2,420	240	25,240	12,780	148 460	.	....
5081	0-6	Greene	Silt loam	8,510	768	9,730	2,982	746	58	37,846	1,530	9,400	0	Acid
5082	6-36	"	"	11,420	1,378	9,682	3,302	704	2	40,038	920	......	0	Sl. alkaline
5083	0-6	"	"	7,722	1,268	12,552	5,218	1,134	276	35,782	3,634	26,800	3,600	Alkaline
5279	0-6	Hamilton	Silt loam	12,166	426	15,724	3,712	1,184	52	32,880	2,340	25,000	0	Acid
5280	6-36	"	"	22,502	612	14,986	2,720	1,130	26	39,132	1,164	......	0	"
10752	0-6	"	"	7,000	440	6,000	2,930	1,222	8	29,916	2,794	......	0	Sl. acid
10756	0-6	"	"	9,866	.....	4,802	1,550	642	34	33,012	2,794	......	.	....
10759	0-6	"	Clay loam	20,738	.....	23,608	19,936	3,062	2,810	61,444	.....	......	.	....
5281	0-6	"	"	40,250	2,110	56,266	19,298	6,116	2,558	55,832	3,844	30,000	4,300	Alkaline
5282	6-12	"	"	28,108	4,286	47,914	35,846	6,228	3,242	64,216	.....	......	.	"
5283	0-6	"	Silt loam	19,250	822	35,010	10,290	5,610	2,418	41,388	5,164	44,200	0	Acid
5531	0-6	Hancock	Clay loam	6,562	540	9,500	3,430	1,068	10	36,420	3,554	......	.	....
5532	6-36	"	"	6,868	532	8,600	2,720	794	4	38,160	2,374	......	.	....
14163	....	Hardin	Blk. clay loam	......	.....	20,880	14,720	2,020	340	40,480	8,020	63,600	0	....
5401-1	0-6	Jefferson	Silt loam	8,772	278	6,590	3,520	1,236	22	37,072	1,348	.....	1,700	Alkaline
5401-2	6-36	"	"	10,894	574	6,000	3,830	1,116	24	43,906	726	......	600	Neutral
4709	0-6	Lucas	Sand	5,238	198	12,890	1,026	554	114	26,400	1,430	18,200	0	Sl. acid
4710	6-36	"	"	7,568	142	12,844	682	252	24	29,110	510	......	0	Sl. acid
4711	0-6	"	"	5,238	170	14,302	1,084	502	50	27,528	1,700	29,400	0	"
4701	0-6	"	Sandy loam	8,558	810	21,100	8,160	1,056	344	34,910	5,424	67,000	500	Alkaline
4702	6-36	"	"	10,308	1,022	17,454	5,062	762	344	35,456	1,290	......	400	Sl. alkaline
4703	0-6	"	"	8,334	714	18,640	7,334	986	234	34,580	4,884	52,600	400	Sl. acid
4704	0-6	"	"	7,504	526	19,460	5,200	934	274	28,658	3,660	40,800	0	Sl. acid
4705	6-36	"	"	7 152	740	17,902	2,302	752	288	31,394	974	......	100	Neutral

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium Total	Magnesium Soluble*	Calcium Total	Calcium Soluble*	Phosphorus Total	Phosphorus Soluble*	Potassium	Nitrogen	Humus	CaCO₃† in soil	Reaction to litmus paper
4699	0-6	Lucas	Clay	10,078	678	9,306	2,023	1,088	82	40,650	2,446	24,200	0	Acid
4700	6-36	"	"	18,528	1,990	9,332	2,452	804	26	53,444	1,220	.....	0	"
4696	0-6	"	Clay	12,698	872	19,412	6,982	1,312	106	43,164	5,094	46,200	0	Sl. acid
4697	6-36	"	"	16,860	1,494	14,180	7,052	788	126	47,872	1,754	......	3,500	Alkaline
4698	0-6	"	"	16,812	4,286	21,028	15,118	996	154	43,934	4,460	37,600	25,600	Neutral
4706	0-6	"	"	10,488	1,634	20,526	7,072	1,562	404	37,006	6,544	67,800	0	Sl. acid
4707	6-36	"	"	12,106	1,838	15,210	4,342	1,044	384	40,326	1,740	.....	400	Sl. alkaline
4708	0-6	"	"	8,214	1,138	17,362	5,066	1,264	88	34,362	5,640	57,600	50	"
10743	0-6	Miami	Silt loam	13,476	724	10,136	3,850	1,748	88	43,200	3,990	......	0	Sl. acid
10763	0-6	"	"	7,876	314	11,016	3,830	1,234	18	36,364	4,050	......	0	Sl. acid
10734	0-6	Montgomery	"	12,470	520	9,400	1,990	720	206	37,394	2,414	......	1,000	Sl. alkaline
10736	0-6	"	"	12,534	654	11,414	3,162	806	30	35,720	.....	......	...	....
10735	0-6	"	Clay loam	19,798	976	18,598	11,120	2,444	106	41,200	.....	......	...	....
10732	0-6	"	Silt loam	8,948	494	11,218	2,850	576	62	36,492	1,850	......	550	Sl. alkaline
10733	0-6	"	Clay loam	15,970	532	18,892	1,990	1,906	20	43,452	5,160	......	...	....
4752	0-6	"	"	6,388	454	8,026	2,600	794	8	39,196	2,074	18,200	...	.. .
4753	6-36	"	"	12,600	1,062	8,854	3,208	936	10	43,584	1,080	.....	...	....
4754	0-6	"	Blk. clay loam	12,994	2,592	19,752	12,766	1,486	38	35,782	6,154	61,800	4,400	Alkaline
4755	0-6	"	"	17,500	9,952	36,584	28,776	1,302	22	34,556	5,960	56,800	74,000	Str. alk'line
10728	0-6	"	Clay loam	6,036	416	9,100	2,674	670	18	33,520	2,120	3,400	...	....
4639	0-6	Mahoning	"	10,662	336	5,472	1,606	1,168	26	33,204	4,120	48,000	0	Acid
4640	0-6	"	"	12,032	236	5,280	1,536	908	10	31,720	3,590	37,600	0	"
4641	0-6	"	"	10,662	406	6,528	2,834	1,118	8	31,204	4,060	37,800	0	"
4642	0-6	"	"	10,060	286	5,184	1,662	822	6	31,204	3,390	50,000	0	"
4643	0-6	"	"	11,586	346	5,136	1,626	1,076	8	31,140	3,890	39,200	0	"
9702	0-6	Meigs	Silt loam	6,016	292	4,000	1,926	722	8	29,260	2,694	......	...	....
9703	0-6	"	Silt loam	5,644	304	3,200	1,810	690	12	30,760	2,974	......	...	....
9704	0-6	"	"	5,512	274	3,600	2,280	848	8	30,820	2,930	31,800	...	....

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	CaCO3 † in soil	Reaction to litmus paper
	inches			Total	Soluble*	Total	Soluble*	Total	Soluble*					
10738	0-6	Preble	Clay loam	44,472	28,700	84,600	56,800	1,694	210	35,202	3,320	......	239,000	Str. alk'line
10737	0-6	"	Silt loam	15,116	766	10,530	2,500	580	14	36,880	1,820	......	0	Sl. alkaline
10739	0-6	"	"	8,992	690	10,332	3,960	964	48	36,558	2,874	......	650	Alkaline
10740	0-6	"	Clay loam	14,592	4,288	19,386	8,150	1,808	236	37,912	5,480	......	550	Sl. alkaline
4722	0-6	Putnam	Sandy loam	6,268	584	16,960	5,818	1,122	38	36,618	4,194	34,400	200	Alkaline
4723	6-36	"	"	10,444	894	16,286	6,346	768	46	35,200	1,434	......	300	"
4724	0-6	"	"	5,512	420	14,402	4,716	1,228	18	36,810	4,510	35,900	600	Sl. alkaline
4727	0-6	"	"	7,718	366	8,426	5,318	906	236	35,324	3,804	31,000	0	Neutral
4728	6-36	"	"	12,300	418	6,134	3,758	578	78	37,136	1,524	......	0	Sl. alkaline
4716	0-6	"	Bl'k, clay loam	14,066	1,334	16,720	8,448	1,948	276	48,160	3,960	41,800	350	Sl. alkaline
4717	6-36	"	"	10,500	1,614	13,882	7,290	1,694	294	48,672	2,490	......	500	Neutral
4718	0-6	"	"	11,100	1,388	14,466	8,506	2,346	150	49,512	7,464	64,800	100	Acid
4719	0-6	"	Clay loam	10,564	1,020	7,334	2,068	1,086	16	48,386	3,404	32,200	0	"
4720	6-36	"	"	14,600	1,342	6,258	4,846	654	14	55,022	1,534	......	0	"
4721	0-6	"	"	13,542	1,090	12,844	5,418	1,396	26	45,418	4,714	28,800	600	Sl. acid
4725	0-6	"	Sandy clay	6,692	730	13,682	5,632	1,432	40	37,038	3,850	36,000	400	Sl. alkaline
4726	6-36	"	"	5,456	860	14,152	4,774	924	32	38,906	1,874	......	0	Neutral
14168	....	Sandusky	Sand	.....	......	17,420	40	940	140	32,900	1,400	......	...	....
10755	0-6	Warren	Sandy loam	24,720	15,838	80,774	71,694	2,638	1,934	35,720	.....	......	...	Str. alk'line
10753	0-6	"	Silt loam	7,198	456	6,788	2,440	1,180	32	31,786	.....	......	...	....
10754	0-6	"	"	6,498	328	6,688	2,450	1,064	24	31,076	.....	......	...	....
10757	0-6	"	"	5,862	252	5,508	1,374	704	8	27,854	2,100	......	...	....
10760	0-6	"	"	7,700	312	6,098	1,866	1,042	24	37,910	2,100	......	0	Acid
10761	0-6	"	"	10,104	774	12,784	6,060	1,508	34	38,428	4,730	......	400	Neutral
10762	0-6	"	"	7,154	432	8,952	4,766	1,888	172	38,558	2,530	......	0	Neutral
10764	0-6	"	Clay loam	17,348	2,898	22,918	15,300	2,668	500	49,000	2,060	......	24,250	Sl. alkaline

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Concluded. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	$CaCO_3$ † in soil	Reaction to litmus paper
	inches			Total	Soluble*	Total	Soluble*	Total	Soluble*					
4690	0-6	Wayne	Gravelly loam	7,624	156	7,200	812	1,140	72	30,368	2,360	22,600	0	Acid
4691	6-36	"	"	10,216	340	6,276	458	782	8	31,590	914	......	0	"
4688	0-6	"	Sandy loam	5,490	160	8,962	884	554	6	24,178	2,434	30,000	0	"
4689	6-36	"	"	6,628	246	9,778	636	270	2	26,112	490	......	0	"
4673	0-6	"	Silt loam	7,546	206	5,398	966	806	30	34,138	2,010	24,000	0	Sl. acid
4674	0-6	"	"	6,996	390	6,810	1,698	1,086	48	33,784	3,074	43,400	0	"
4675	0-6	"	"	7,468	260	6,380	1,178	812	4	33,780	2,450	30,000	0	"
4676	6-36	"	"	10,530	610	5,884	1,238	686	2	35,878	960	......	0	Neutral
4677	0-6	"	"	6,254	178	5,106	600	782	6	32,236	2,454	32,400	0	Acid
4679	0-6	"	"	6,922	242	5,018	990	1,008	8	34,204	2,660	32,400	0	"
4680	0-6	"	Clay loam	7,862	258	5,350	1,154	692	4	32,816	2,274	24,800	0	Sl. acid
4681	0-6	"	"	7,450	224	6,812	1,414	786	2	30,882	2,744	23,600	0	Acid
4682	6-36	"	"	10,588	558	6,812	1,344	442	2	36,748	1,100	......	0	"
4683	0-6	"	"	6,934	...	8,562	2,406	886	4	29,658	3,284	32,200	0	"
4684	0-6	"	"	7,766	434	7,396	2,074	1,020	8	32,172	3,284	31,400	0	"
4685	0-6	"	Clay	13,584	1,080	8,660	5,766	1,928	46	41,134	6,860	68,800	0	"
4686	6-36	"	"	10,544	378	6,032	2,122	1,176	244	36,620	1,854	......	0	"
4687	0-6	"	"	6,660	242	5,108	1,414	848	4	28,884	2,644	30,600	0	Sl. acid
14101	0-6	Washington	Clay	.....	...	10,140	7,760	1,140	260	49,240	2,120	19,160	.	......

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE III: Giving location and description of soils studied.

Lab. No.	County	Township	Depth inches	Classification	Description
4644	Ashtabula	Saybrook	0-6	Silt loam	2¼ mi. northeast of Austinburg. Timothy meadow with only a fair stand of grass and considerable sorrel. Mapped by the Bureau of Soils, U. S. D. A. as Volusia loam.
4645	Ashtabula	Saybrook	6-36	Silt loam	
4646	Ashtabula	Saybrook	0-6	Silt loam	Virgin timber soil ¼ mi. west of 4644 and 4645.
4647	Ashtabula	Conneaut	0-6	Silt loam	5 mi. southeast of Conneaut, 2 mi. west of South Ridge Road. Timothy meadow, grass poor, topography quite rolling. Mapped by Bureau of Soils, U. S. D. A. as Volusia loam.
4648	Ashtabula	Saybrook	0-6	Gravelly loam	5 mi. north of Austinburg. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravelly loam.
4649	Ashtabula	Saybrook	6-36	Gravelly loam	
4650	Ashtabula	Saybrook	0-6	Gravelly loam	Maple grove 30 rods north of 4648 and 4649.
4651	Ashtabula	Kingsville	0-6	Gravelly loam	2 mi. southwest of Amboy and 5 mi. west by southwest from Conneaut. Timothy meadow, grass poor. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravelly loam.
4652	Ashtabula	Saybrook	0-6	Gravel	5¼ mi. north of Austinburg, 10 rods from Nickel Plate railroad. Timothy meadow, grass poor. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravel.
4654	Ashtabula	Conneaut	0-6	Gravel	3½ mi. southwest of Conneaut. Field was in wheat 1908. Timothy was sown but failed for 1909 crop. Sorrel in almost absolute possession. Large gravel extremely more abundant than in same type (4652) from different source. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravel.
4655	Ashtabula	Saybrook	0-6	Clay	2 mi. north of Saybrook Corners. In timothy. Fair grass. Considerably darker in color than described by Bureau of Soils. Mapped by Bureau of Soils, U. S. D. A., as Dunkirk clay.
4656	Ashtabula	Saybrook	6-36	Clay	
4657	Ashtabula	Saybrook	0-6	Clay	Virgin timber soil. 2½ inches to yellow clay. About ½ mi. east of 4655 and 4656.
4658	Ashtabula	Saybrook	0-6	Sandy loam	2 mi. southeast of Ashtabula city, ¼ mi. north of Nickel Plate tracks. Corn 1908, uncultivated 1909. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk sandy loam.
4659	Ashtabula	Saybrook	6-36	Sandy loam	
4660	Ashtabula	Conneaut	0-6	Sandy loam	Virgin 2 mi. west of Conneaut, 10 rods north of Lake Shore railroad on left of road. Native timber, spruce or cedar. Mapped by Bureau of soils, U. S. D. A. as Dunkirk sandy loam.
4661	Ashtabula	Conneaut	0-6	Sandy loam	2½ mi. west of Conneaut. Timothy very poor, sorrel abundant, 45 rods north of 4660. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk sandy loam.
4662	Ashtabula	Plymouth	0-6	Sandy loam	Waste land or pasture. In plot on right of north and south road at end of viaduct in Ashtabula city and about 20 rods south of Nickel Plate tracks. Mapped by Bureau of Soils, U. S. D. A. as meadow.
4730	Allen	....	0-6	Clay loam	Virgin from blue grass pasture, farm of Adam Bame. Has not been plowed for over 10 years. Bed rock limestone about 6 feet beneath surface. Subsoil brownish yellow, large amounts of rotten limestone perceptible.
4731	Allen	....	6-36	Clay loam	
4732	Allen	....	0-6	Clay loam	30 rods east of 4730. Farm of Adam Bame. Timothy meadow.

TABLE III. Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
4733	Allen	....	0-6	Silt loam	Cornfield adjoining Bluffton Stone Co.'s quarry on the east. Limestone gravel at about 20-24 inches. Farmed in corn for a number of years.
10744	Auglaize	Washington	0-6	Black clay loam	Upland, timber, 3 inches to color line. Limestone 15-25 feet.
10745	Auglaize	Washington	0-6	Black clay loam	Upland pocket black clay loam, 8 inches to color line. Limestone 15-25 feet.
10746	Auglaize	Washington	0-6	Silt loam	Upland grey silt loam, 8 inches to color line. Limestone 15-25 feet.
5286	Brown	....	0-6	Silt loam	Virgin sample from Mr. Tracy's farm known as "Hill Top Farm." From woodlot southeast of house.
5287	Brown	....	6-36	Silt loam	
5288	Brown	....	0-6	Silt loam	From Mr. Tracy's farm, from field adjoining and southeast of barn. Corn 1909, yield 40 bu. Poor clover in 1908. Soil probably representative of that community.
5289	Brown	....	6-36	Silt loam	
5294	Brown	....	0-6	Silt loam	From Mr. Tracys' farm, from field adjoining and southeast of barn. Good clover 1909.
10750	Butler	Madison	0-6	Clay loam	Second bottom blue clay loam, 6 inches to color line, limestone pebbles exposed.
10751	Butler	Madison	0-6	Sandy loam	First bottom fine sandy loam, 16 inches to color line, limestone pebbles scattered in soil.
4565	Butler	....	0-6	Silt loam	From test plots on farm of J. C. Overpeck, Hamilton, O., R. F. D. No. 7.
4566	Butler	....	6-36	Silt loam	
4567	Butler	....	0-6	Silt loam	From test plots on farm of J. J. Kennel, Trenton, O., R. F. D. No. 1.
4568	Butler	....	6-36	Silt loam	
4741	Clarke	....	0-6	Black clay loam	8½ mi. southeast of Springfield, farm of E. J. Kitchen. Soil is mainly of alluvial or swamp origin, and is underlaid at about 15 in. by tenacious drab-colored clay. Locally known as "Gumbo." This field has been in corn for 17 years in succession, and gave promise of 50-60 bu. per acre in 1909. Water was encountered at about 3 ft. below the surface.
4742	Clarke	....	6-36	Black clay loam	
4743	Clarke	....	0-6	Black clay loam	Fence row.
4744	Clarke	....	0-6	Silt loam	From farm of E. J. Kitchen. Brown silt loam underlaid by a reddish yellow, gravelly loam.
4745	Clarke	....	6-36	Silt loam	
4746	Clarke	....	0-6	Silt loam	Fence row.
4747	Clarke	....	0-6	Silt loam	Upland silt loam, underlaid by a subsoil containing fine gravel and corresponding closely with sample 4745.
4748	Clarke	....	6-36	Silt loam	
4749	Clarke	....	0-6	Silt loam	5 mi. north of Springfield. From farm of R. L. Holman. Alfalfa meadow 3 years old and showing fine stand. Soil is a brown friable loam underlaid by a yellowish gravel subsoil containing an abundance of limestone pebbles at a depth of 20 inches.
4750	Clarke	....	6-36	Silt loam	
4751	Clarke	....	0-6	Silt loam	4751 is from pasture cleared from forest about 1860, and has not been plowed for at least 40 years.

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
4663 4664	Cuyahoga Cuyahoga	Bedford Bedford	0-6 6-36	Clay loam Clay loam	2½ mi. southwest of Bedford. Timothy fair. Mapped by Bureau of Soils, U. S. D. A., as Miami clay loam.
11381	Cuyahoga	....	0-6	Clay	From Sec. B, 5-yr. rotation of the Strongsville Test Farm.
4665 4666	Cuyahoga Cuyahoga	Bedford Bedford	0-6 6-36	Stony loam Stony loam	4 mi. southwest of Bedford. Corn 1908. Stalks small, indicating poor crop. Uncultivated 1909. Mapped by Bureau of Soils, U. S. D. A., as Miami stony loam.
4667	Cuyahoga	Bedford	0-6	Stony loam	150 ft. south of 4665 and 4666 in corner of woodlot. In timothy but evidently quite recently broken, grass fair. Mapped by Bureau of Soils, U. S. D. A. as Miami stony loam.
4668 4669	Cuyahoga Cuyahoga	Independence Independence	0-6 6-36	Sandy loam Sandy loam	1 mi. east of Alexander, cornfield. Corn good. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk sandy loam.
4670	Cuyahoga	Independence	0-6	Gravelly loam	½ mi north of Alexander; cornfield. Not fertilized. Corn fine. Subsoil too gravelly to bore. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravelly loam.
4671 4672	Cuyahoga Cuyahoga	Independence Independence	0-6 6-36	Clay loam Clay loam	1½ mi. north of Alexander. Bottom land. Timothy fair. Wild morning glory abundant. (Soil somewhat sticky.) 6-28 in. in stiff clay. 28-36 in. sandy. Mapped by Bureau of Soils, U. S. D. A. as Wabash loam.
5284 5285	Clermont Clermont	....	0-6 6-36	Silt loam Silt loam	2 mi. east of Batavia. Farm of Mr. Reed. From 8-acre field east of house. Typical farm land of that section of the county.
5293	Clermont	....	0-6	Silt loam	From alfalfa field north of house. Alfalfa poor, probably needs lime and drainage.
10756	Clermont	....	0-6	Silt loam	Upland grey silt loam, 10 in. to color line, limestone rock at 25 ft.
4712 4713	Defiance Defiance	Noble Noble	0-6 6-36	Clay loam Clay loam	2 mi. west of Defiance. Farm of E. G. Hudson. A dark colored clay soil to a depth of about 7 in. Subsoil to a depth of 20-24 in. consists of a compact yellow clay underlaid by a greyish blue clay. This type is prevalent for miles along the river.
4714	Defiance	Noble	0-6	Clay loam	Fence row, road side.
4715	Defiance	Highland	0-6	Clay	5 mi. southeast of Defiance on Ottawa Pike. Soil is very stiff tenacious clay, dark yellow color, slightly more granular than 4712. The color line here lies nearer the surface than in 4712, and the yellow subsoil stratum is only about 16-18 in. deep. It is difficult to drain this soil, because the tenacious clay subsoil cements over the tile joints; open ditches become filled up in from 12 to 18 months.
10766	Darke	Greenville	0-6	Clay loam	First bottom clay loam. 8 in. to color line.
10768	Darke	Greenville	0-6	Clay loam	Wooded upland, grey clay loam. 2 in. to color line.
10769	Darke	Twin	0-6	Silt loam	Upland brown silt loam. 8 in. to color line.
10767	Darke	Greenville	0-6	Clay loam	Upland grey clay loam.

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
10770	Darke	Buren	0-6	Silt loam	Upland timber, brown silt loam. 3 in. to color line. U. S. elevation 1,040 ft.
10771	Darke	Buren	0-6	Silt loam	Upland brown silt loam. 8 in. to color line. U. S. elevation 1,040 ft.
10772	Darke	Twin	0-6	Silt loam	Upland brown silt loam. Wooded pasture. 3 in. to color line.
4734	Franklin	....	0-6	Clay loam	6 mi. east of Columbus. South of Broadstreet Pike and ½ mi. west of Columbus, Sandusky and Hocking railroad. Light brown loam underlaid by stiff mottled clay containing some gravel and course sand. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4735	Franklin	....	6-36	Clay loam	
4736	Franklin	....	0-6	Clay loam	Open woodland.
4737	Franklin	....	0-6	Black clay loam	¼ mi. north of National Pike and 1 mi. west of Columbus, Sandusky and Hocking railroad. Black clay loam 12-16 in. deep, underlaid by a stiff yellow clay. Mapped by Bureau of Soils, U. S. D. A. as Miami black clay loam.
4738	Franklin	....	6-36	Black clay loam	
4739	Franklin	....	0-6	Black clay loam	Fence row.
4740	Franklin	....	0-6	Clay loam	River terrace 1 mi. north of Storage Dam on west side of Scioto river, and opposite Wyandot Club House. Soil 10-15 in. deep and full of rock fragments. Bed limestone rock at 10-15 in. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
5085	Franklin	....	1-14	Clay loam	Probably 80 ft. to limestone.
5088	Franklin	....	14-24	Clay loam	Subsoil of 5085.
5087	Franklin	....	1-14	Black clay	Black swale.
5086	Franklin	....	14-24	Black clay	Black swale. 5085, 5086, 5087 and 5088 are from farm of P. J. McCoy, Station A, Route 2, Columbus, Ohio. 1½ mi. from Storage Dam and west of Scioto river.
14169	Fulton	....		Sand	
5081	Greene	....	0-6	Silt loam	Soldiers' and Sailors' Orphans' Home, Xenia, Ohio. Clover field.
5082	Greene	....	6-36	Silt loam	Subsoil of 5081.
5083	Greene	....	0-6	Silt loam	Woodlot, uncultivated.
5084	Greene	....	0-6	Silt loam	From plot planted in alfalfa.
5279	Hamilton	....	0-6	Silt loam	1 mi. east of Madisonville on Richard's farm. From top of hill, south field. Seeded to alfalfa 1908, not very good.
5280	Hamilton	....	6-36	Silt loam	
5281	Hamilton	....	0-6	Clay loam	1 mi. east of Madisonville. From hillside of south field on Richard's farm. Alfalfa for 20 years, fine crop. Limestone outcrop and stones all over field. Could not go down deeper than 12 inches.
5282	Hamilton	....	6-12	Clay loam	
5283	Hamilton	....	0-6	Silt loam	1 mi. east of Madisonville on Richard's farm. From pasture field south of house. Could not get subsoil on account of limestone rock.

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
10752	Hamilton	Anderson	0-6	Silt loam	Upland grey silt loam. 9 in. to color line.
10758	Hamilton	Anderson	0-6	Silt loam	Upland silt loam.
10759	Hamilton	Anderson	0-6	Clay loam	Upland clay hillside, limestone rock on surface.
5531	Hancock	....	0-6	Clay loam	Composite samples from Findlay Test Farm.
5532	Hancock	....	6-36	Clay loam	
14163	Hardin	Marion	......	Black clay loam	From farm near McGuffey, Ohio. Prairie soil.
5401-1	Jefferson	....	0-6	Silt loam	Mt. Pleasant, Ohio. Farm of Geo. E. Scott.
5401-2	Jefferson	....	6-36	Silt loam	
4696	Lucas	Waynesfield	0-6	Clay	1 mi. northwest of Maumee on Holland road, 40 rods northwest of flat-roofed brick house on left of road. Clover sod. Black, somewhat sticky clay loam. Subsoil very tenacious, yellowish clay. Mapped by Bureau of Soils, U. S. D. A. as Miami black clay loam and recorrelated as Clyde clay.
4697	Lucas	Waynesfield	6-36	Clay	
4698	Lucas	Waynesfield	0-6	Clay	From fence row. Blue grass prevailing.
4699	Lucas	Adams	0-6	Clay	3½ mi. north of Maumee. Clover sod. Subsoil mottled brown and grey clay. Corresponds closely with the Bureau's description of Dunkirk clay loam, but the type appears to be quite variable, as sandy soil was found in the same field, and on practically the same level. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4700	Lucas	Adams	6-36	Clay	
4701	Lucas	Adams	0-6	Sandy loam	3 mi. north of Maumee, ¼ mi. west of 4699 and 4700 in same area, but quite different in character. Samples were taken from field of alfalfa 2 years old, fine stand. Soil to a depth of 7 to 9 in., black, medium grained, sandy loam, underlaid by yellowish grey sandy subsoil. This type in area mapped as Miami clay loam and recorded by Bureau of Soils, U. S. D. A. as Dunkirk clay, is sufficiently extensive to be classed as a sandy loam.
4702	Lucas	Adams	6-36	Sandy loam	
4703	Lucas	Adams	0-6	Sandy loam	Open woodland.
4704	Lucas	Adams	0-6	Sandy loam	5 mi. north of Maumee and ½ mi. south of L. S. & M. S. R. R. Black sandy loam to a depth of 7-10 in. and closely resembles 4701, but seems to be a little more sandy, darker colored and coarser. Subsoil to a depth of 30 in. is a drab or grey colored sand. Below 30 in. it is a yellow sand. Mapped by Bureau of Soils, U. S. D. A. as Miami sandy loam.
4705	Lucas	Adams	6-36	Sandy loam	
4706	Lucas	Adams	0-6	Black clay	¾ mi. north of 4704, in the same area, and mapped as Miami sandy loam by the Bureau of Soils, U. S. D. A. In reality the soil as found at this point is a black clay containing apparently but a small percentage of sand. The type is quite extensive. The black clay extends to a depth of 7-9 in. underlaid by a mottled, stiff, sticky clay.
4707	Lucas	Adams	6-36	Clay	
4708	Lucas	Adams	0-6	Black clay	Open woodland.
4709	Lucas	Adams	0-6	Sand	5 mi. north of Maumee, 1 mi. east of 4706, ½ mi. north of L. S. & M. S. R. R. Mapped by Bureau of Soils, U. S. D. A. as Miami sand.
4710	Lucas	Adams	6-36	Sand	
4711	Lucas	Adams	0-6	Sand	Fence row (rd. Sd.)

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
10743	Miami	Washington	0-6	Silt loam	Second bottom brown silt loam. 8 in. to color line, limestone gravel outcrops and runs about 2 ft. from surface.
10763	Miami	Washington	0-6	Silt loam	Upland brown silt loam. 6 in. to color line, gravel and limestone pebbles at 15 in.
10732	Montgomery	Jackson	0-6	Silt loam	Upland grey silt loam. 5 in. to color line.
10733	Montgomery	Jackson	0-6	Clay loam	Upland black pocket. 10 in. to color line.
10734	Montgomery	Jackson	0-6	Silt loam	Upland clay loam. Limestone pebbles at 2 ft. 7 in. to color line.
10735	Montgomery	Jackson	0-6	Clay loam	Upland clay loam. Dark pocket, virgin soil. 9 in. to color line.
10736	Montgomery	Jackson	0-6	Silt loam	Upland timber. 3 in. to color line.
4754	Montgomery	....	0-6	Black clay loam	6 mi. southwest of Dayton and ½ mi. to the right of the Germantown Pike.
4755	Montgomery	....	0-6	Black clay loam	Virgin, from fence row.
10728	Montgomery	....	0-7	Clay loam	From tobacco plots of S. W. Substation, Germantown, Ohio.
4752	Montgomery	....	0-6	Clay loam	Alfalfa field on left of Germantown pike, 5 mi. southwest of Dayton, field adjoining limestone quarry. The soil and subsoil show very little differentiation, except that the latter is somewhat more compact.
4753	Montgomery	....	6-36	Clay loam	
9702	Meigs	....	0-7	Silt loam	From S. E. Substation, Carpenter, Ohio. Sec. B, Plot 16.
9703	Meigs	....	0-7	Silt loam	East border of Sec. B.
9704	Meigs	....	0-7	Silt loam	North border of Sec. A.
4639	Mahoning	....	0-6	Clay loam	From Boardman field. Composite of Plots 1-4-7-10, Sec. A. Grew potatoes 1908, fertilizer corn 1909.
4640	Mahoning	....	0-6	Clay loam	Boardman field. Composite of Plots 1-4-7-10, Sec. B, wheat 1908, variety soybeans 1909.
4641	Mahoning	....	0-6	Clay loam	Boardman field. Composite of Plots 1-4-7-10, Sec. E, proposed alfalfa test 1909. wheat 1908. East end quite wet.
4642	Mahoning	....	0-6	Clay loam	Boardman field. Composite of Plots 1-4-7-10, Sec. C, wheat 1908, variety corn 1909.
4643	Mahoning	....	0-6	Clay loam	Boardman field. Composite of Plots 1-4-7-10, Sec. D, orchard grass. Sod turned under and medium green soybeans planted in 1909.
10740	Preble	Jackson	0-6	Clay loam	Upland black pocket, black clay loam. Sandy at 36 in.; 9 in. to color line.
10739	Preble	Jackson	0-6	Silt loam	Gently rolling upland, grey silt loam. 15 in. to color line.

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
10738	Preble	Lanier	0-6	Clay loam	Level clay loam. 18 in. to color line.
10737	Preble	Lanier	0-6	Silt loam	Upland grey silt loam, gently rolling. 12 in. to color line.
4716	Putnam	Blanchard	0-6	Black clay loam	4 mi. southeast of Ottawa. Farm of Wm. Blodget. Black clay loam, underlaid by a dark colored clay subsoil. Clover fine stand.
4717	Putham	Blanchard	6-36	Black clay loam	
4718	Putnam	Blanchard	0-6	Black clay loam	Open woodland, 40 rods west of 4716.
4719	Putnam	Blanchard	0-6	Clay loam	Farm of J. A. Maidlow. Said to be rather unproductive, is quite hard and cracks in dry weather. Subsoil is tough, mottled clay.
4720	Putnam	Blanchard	6-36	Clay loam	
4721	Putnam	Blanchard	0-6	Clay loam	Fence row.
4722	Putnam	Blanchard	0-6	Sandy loam	Putnam County Infirmary Farm. Alfalfa patch just north of orchard. Soil is a decided sandy loam, containing limestone pebbles or particles of crushed limestone, which may have been applied to the soil at one time. This feature is especially perceptible at the east end of field. Subsoil appears to be mainly a mixture of clay, sand and fine gravel.
4723	Putnam	Blanchard	6-36	Sandy loam	
4724	Putnam	Blanchard	0-6	Sandy loam	School yard adjoining 4722 and 4723.
4725	Putnam	Van Buren	0-6	Sandy clay	Farm of C. Gusar, along south line of Van Buren Tp. and 1¼ mi. from east county line. Red clay soil with perceptible sand content. The subsoil closely resembles the surface to a depth of 20-36 in. Below 36 in. is a thin stratum of yellowish clay underlaid by a stratum of creek sand. Soil appears to be quite fertile. Corn good stand.
4726	Putnam	Van Buren	6-36	Sandy clay	
4727	Putnam	Pauline	0-6	Sandy loam	Surface is a sandy loam underlaid by a sandy subsoil, not much different in character from surface except being lighter in color, due doubtless to a larger amount of organic matter in surface. Wheat stubble indicated fine crop.
4728	Putnam	Pauline	6-36	Sandy loam	
10753	Warren	Deerfield	0-6	Silt loam	Upland grey to brown silt loam. 6 in. to color line. Limestone outcrops 1 mi. northwest on same level.
10754	Warren	Deerfield	0-6	Silt loam	Upland grey silt loam. Wooded pasture. 3 in. to color line. Limestone outcrops ¼ mi. northwest on same level.
10755	Warren	Hamilton	0-6	Sandy loam	Little Miami river bottom, fine sandy loam. 21 in. to color line. Limestone pebbles on river bottom.
10757	Warren	Deerfield	0-6	Silt loam	Upland grey silt loam. 6 in to color line. Limestone outcrops 1 mi. northwest on same level.
10760	Warren	Union	0-6	Silt loam	Upland reddish grey silt loam. 3 in. to color line. Limestone rock at 20-25 ft.
10761	Warren	Turtle Creek	0-6	Silt loam	Upland black loam. 13 in. to color line. Infirmary Farm.
10762	Warren	Union	0-6	Silt loam	Second bottom grey silt loam. 8 in. to color line. Limestone outcrops in surrounding hills.

TABLE III: Giving location and description of soils studied.—Concluded

Lab. No.	County	Township	Depth inches	Classification	Description
10764	Warren	Turtle Creek	0-6	Clay loam	Upland grey clay loam, hillside: 5 in. to color line. Limestone scattered on surface.
4673	Wayne		0-6	Silt loam	2¼ mi. north of Wooster, Bruce field. Timothy very poor, weeds in possession, sorrel, hood leaf and plantain predominating. Heavily farmed for years with very little fertilization. Mapped by Bureau of Soils, U. S. D. A. as Volusia silt loam.
4674	Wayne		0-6	Silt loam	From fence row of Bruce field.
4675 4676	Wayne Wayne		0-6 6-36	Silt loam Silt loam	¼ mi. north of Madisonburg. Oats good. Not much differentiation in color between soil and subsoil to 36 in. depth. Below 36 in. begin to strike gravelly stratum. Mapped by Bureau of Soils, U. S. D. A. as Volusia silt loam.
4677	Wayne		0-6	Silt loam	1½ mi. north of Madisonburg. Oats fair. Soil evidently in poorer tilth than 4675. Mapped by Bureau of Soils, U. S. D. A. as Volusia silt loam.
4679	Wayne		0-6	Silt loam	5 mi. northeast of Wooster. Timothy very good. (Grady farm.) Mapped by Bureau of Soils, U. S. D. A. as Volusia silt loam.
4680	Wayne		0-6	Clay loam	3 mi. north of Madisonburg. Corn 1909. Sod plowed down. Crop fertilized in row. Samples were taken directly from between the rows. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4681 4682	Wayne Wayne		0-6 6-36	Clay loam Clay loam	2 mi. south of Creston. Wheat fair to good. No clover. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4683	Wayne		0-6	Clay loam	Virgin timber joining field from which 4681 and 4682 were taken.
4684	Wayne		0-6	Clay loam	4 mi. north of Smithville. Timothy good. Subsoil mottled yellow and grey. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4685 4686	Wayne Wayne		0-6 6-36	Clay Clay	1 mi. southwest of Sterling. Timothy very good. Soil very black and sticky. Is typical of the darker colored local areas of the Waverly clay type, as described by the Bureau of Soils. Mapped by Bureau of Soils, U. S. D. A. as Waverly clay.
4687	Wayne		0-6	Clay	Permanent pasture. Not as black as 4685 and according to Bureau of Soils, more typical of larger areas of type. Subsoil at 18 in. more yellow than 4686. Mapped by Bureau of Soils, U. S. D. A. as Waverly clay.
4688 4689	Wayne Wayne		0-6 6-36	Sandy loam Sandy loam	2½ mi. southwest of Sterling. Timothy fair. Mapped by Bureau of Soils, U. S. D. A. as Miami sandy loam.
4690 4691	Wayne Wayne		0-6 6-36	Gravelly loam Gravelly loam	3 mi. southeast of Sterling. Timothy fair. Below 30 in. gravel and sand much more abundant than in upper stratum of subsoil. Mapped by Bureau of Soils, U. S. D. A. as Miami gravelly loam.

COMPOSITION OF DIFFERENT SOIL TYPES

In classifying the soils sampled, the terms applied by the Bureau of Soils, U. S. Dept. of Agriculture, have been used when the soils were secured from areas surveyed and mapped by that Bureau. Where samples were taken from sections not mapped the soils were classified according to color and texture.

The distinguishing characteristics of different soil types are chiefly those aside from their chemical composition. Differentiations are generally based on texture, color, geological origin, physical or mechanical properties, depth of surface soil, presence of greater or less quantities of organic matter, topography and drainage conditions. The mineral particles which are present in different degrees of fineness as sand, silt and clay determine the soil texture. The mineral content of a sandy soil may not vary greatly from that of a clay soil. Soil particles of different grades of fineness are the result of disintegration of rocks through mechanical, chemical, and biological agencies and may be feldspar, quartz, limestone, mica or other minerals, so that often fine particles classed as clays include a considerable amount of quartz, while the sands may be made up largely of other minerals than quartz. Except in the case of soils largely of organic formation—peats—the bulk of the material which composes a sand, silt or clay is silica or quartz.

Chemically pure or true clay is a compound of silica and alumina containing no potassium or other constituents which contribute towards plant growth. The term clay, used in describing soils, refers to the soil texture and denotes soil particles of a diameter of less than .0002 of an inch.

The physical distinction made between sands, silts and clays, does not necessarily indicate that there is more true clay in soils made up of finer particles than in those of coarser texture.

The composition of the mechanical separations of soils which, in the order of their size are sand, silt and clay, shows that as the degree of fineness increases so does the proportion of soluble constituents. It would be expected therefore that clay soils would differ chemically from silts, and silts from sandy soils.

No marked variation has been found in the total amounts of the elements present in the several grades of soil: the clays and clay loams generally contain less silicon, and somewhat larger amounts of iron, aluminum, potassium and phosphorus than the soils of coarser texture.

TABLE IV. Giving average composition of the several classes of soil. Divided into calcareous and non-calcareous. Surface soil 0-6 inches.

	Silicon	Iron	Aluminum	Calcium	Magnesium	Phosphorus	Potassium	Nitrogen	Humus
Calcareous Sands and Sandy Loam Soils.									
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Total..................	33.1700	2.0550	4.6790	1.9372	.8056	.0652	1.659	.1926	1.90
N-5 HNO3 Soluble.....	.0301	.0369	.1263	1.3279	.3286	.0201	.....	.....	....
Percent of total, soluble in N-5 HNO3........	.0900	1.8000	2.6900	68.5600	40.7800	30.8300	.....	.....	....
Non-calcareous Sands and Sandy Loam Soils.									
Total..................	36.4900	1.7680	4.3590	.5685	.3539	.0548	1.296	.1371	1.63
N-5 HNO3 Soluble.....	.0178	.0298	.1198	.0826	.0102	.0041	.....	.....	....
Percent of total, soluble in N-5 HNO3........	.0490	1.7000	2.7500	14.6000	2.8800	7.4800	.....	.....	....
Calcareous Silts and Silt Loam Soils.									
Total..................	34.9100	2.1440	4.8850	.8076	.5938	.0553	1.846	.1378	1.19
N-5 HNO3 Soluble.....	.0306	.0352	.1181	.3686	.1288	.0045	.....	.....	....
Percent of total, soluble in N-5 HNO3........	.0870	1.6300	2.4100	44.4300	21.6900	8.1300	.....	.....	....
Non-calcareous Silts and Silt Loam Soils.									
Total..................	35.9700	2.1370	4.9840	.4075	.4368	.0514	1.678	.1445	1.63
N-5 HNO3 Soluble.....	.0170	.0194	.1114	.1099	.0197	.0009	.....	.....	....
Percent of total, soluble in N-5 HNO3........	.04600	.8900	2.2200	26.9600	4.5100	1.7500	.....	.....	....
Calcareous Clays and Clay Loam Soils excluding Black Clay Loams.									
Total..................	33.2400	2.6230	5.2500	.7500	.5662	.0709	1.945	.1822	1.48
N-5 HNO3 Soluble.....	.0402	.0576	.1349	.3673	.0952	.0067	.....	.....	....
Percent of total, soluble in N-5 HNO3........	.1200	2.1900	2.5600	48.9700	16.8100	9.4500	.....	.....	....
Non-calcareous Clays and Clay Loam Soils									
Total..................	33.9400	2.5540	5.7460	.3868	.4949	.0516	1.851	.1908	1.91
N-5 HNO3 Soluble.....	.0170	.0405	.1414	.1085	.0254	.0011	.....	.....	....
Percent of total, soluble in N-5 HNO3........	.0500	1.5800	2.4600	28.0600	5.1300	2.1100	.....	.....	....
Black Clay Loam Soils (Calcareous or of Limestone origin).*									
Total..................	29.6600	2.9580	5.4660	1.1795	.6688	.0850	1.835	.3725	3.43
N-5 HNO3 Soluble.....	.0608	.0941	.1927	.7749	.1681	.0082	.....	.....	....
Percent of total, soluble in N-5 HNO3........	.2050	3.1800	3.5300	65.7000	25.2400	9.5600	.....	.....	....

*Only two of the black clay loams sampled contained no calcium carbonate; the subsoils of these two contained calcium carbonate.

Soils classed as being of the same texture often differ widely with respect to their agricultural value, as a result of the presence or absence of calcium carbonate. When the soils are considered with reference to the presence or non-presence of calcium carbonate, greater variations are noticed in the chemical composition of soils of the same class than when a comparison is made between soils classified according to differences in texture.

Table IV, page 469, gives the average composition of the several classes of soils, divided into calcareous and non-calcareous. The calcareous soils all contain less total silicon and larger amounts of total phosphorus and potassium than the non-calcareous soils of the same class; their content of total calcium and magnesium is also greater, as would be expected.

It will be noticed that there is an increase in the solubility of iron, calcium and magnesium in the calcareous soils. There is a decidedly increased amount of soluble phosphorus in the calcareous soils as compared with soils containing no calcium carbonate.

The composition of the black clay loams differs considerably from that of the other classes of soil. These black clay loams were all of limestone origin and contain less total silicon and more nitrogen and phosphorus than the other classes of soil analyzed. Table V, page 477, gives the percents of total and N- 5 nitric acid soluble constituents found in the several classes of soil studied.

SOIL AND SUB-SOIL

The term soil is here used with reference to the layer of soil extending from the surface to a depth of six inches, and the term subsoil is applied to the depth from 6 inches down to 3 feet. Information concerning the underlying soil to the depth of three feet is considered sufficient so far as any effect on the surface soil is concerned. The depths of soil sampled are purely arbitrary since the change from surface soil to subsoil as indicated by color and texture is not always observed at a depth of 6 inches, but varies considerably; when the samples were taken, differences were frequently noted. The first 6 to 7 inches of soil in most cases is the depth which is affected by cultivation, and except where the original soil has been covered with a deposit less rich in organic matter this depth of soil always contains more organic matter than the subsoil.

Phosphorus and nitrogen, the two elements—phosphorus especially—which are most often deficient in Ohio soils, are present to the greatest extent in the surface 6 or 7 inches. Except in a few instances, where the lower soil stratum is found to be liberally supplied with calcium carbonate, phosphorus is always

most abundant in the surface six or seven inches, where it accumulates from plant remains and from leachings by rain and dew on vegetation. A considerable portion of the phosphorus stored in plants, and subsequently returned to the soil, is taken up by the plant roots from soil strata deeper than six or seven inches. Another factor which may contribute to this increased accumulation of phosphorus in the surface soil is the absorbing power of organic matter. As the soil solution carrying phosphorus is continually moving through the soil mass, it may have phosphorus fixed or absorbed from it by organic matter, which is generally present in the largest amount in the upper layer of soil. An indication of the power of organic matter to absorb phosphorus from solution is given by work now in progress on the absorption of phosphorus by soils. The results show that peat soils have this power greatly in excess of what would be expected from their small content of mineral material; and when the organic matter is partially destroyed by oxidation with hydrogen peroxide, the amount of phosphorus absorbed by a peat soil in contact with a solution containing phosphorus is decreased.

Total silicon is present in largest amounts in the surface soil, while the silicon from silicates most readily attacked and taken into solution by the weak acid used—fifth normal nitric acid—increases in the subsoil; greater quantities of total iron, aluminum and potassium are present in the lower strata.

The chief distinction between soils and subsoils is their difference in texture. By the action of various agencies, including cultivation, weathering and bacterial activities, the soil grains are gradually disintegrated and the finer particles carried from the surface to lower depths by the rain water percolating down through the soil, leaving a larger portion of the silicon as quartz in the surface or top soil.

CALCIUM AND MAGNESIUM

An interesting relationship is shown between calcium and magnesium in the two depths of soil analyzed. Comparing the content of these two elements in all soils, regardless of the absence or presence of calcium carbonate, it will be noticed that a greater proportion have more total calcium than magnesium in the surface soil, while in the subsoil the magnesium exceeds the calcium in the greater number of instances. Comparing only the soils containing no calcium carbonate, either in the surface or subsoil, a greater number of the soils have more magnesium than calcium in each depth.

An average of the amounts of these two elements present, however, shows that soils containing no calcium carbonate have a greater percent of calcium in the surface soil than in the subsoil and a greater percent of magnesium in the subsoil.

In soils and subsoils containing calcium carbonate the calcium and magnesium are both found in larger amounts in the subsoil than in the surface. The presence of a larger amount of total calcium in surface soils which contain no carbonates may be explained by the existence of insoluble organic salts of calcium in the surface; this has previously been referred to.

Of forty-two surface soils containing calcium carbonate, the magnesium exceeds the calcium in only five soils. Of the hundred and twenty-six samples of surface soils examined, seventy-three contained more calcium than magnesium and in forty-two of these there were carbonates of calcium or magnesium present. In fifty-four soils containing more magnesium than calcium there were carbonates found in only six samples. Of the forty subsoils examined, sixteen contained more calcium than magnesium and in ten of these carbonates were found. Twenty-four of the subsoils contained more magnesium than calcium and of these only three showed the presence of carbonates. It may be stated that when the magnesium is in excess of the calcium, as a rule, no carbonates are found.

The more readily soluble calcium and magnesium in the two depths follow the same general order as the total calcium and magnesium. In all the soils represented by the samples studied, there is a much larger proportion of calcium than of magnesium soluble in N–5 nitric acid. The difference in calcium and magnesium content is pointed out by the summarized results in Table I, page 451. The reason for the greater amount of magnesium in subsoil than in surface soil is not evident.* Calcium and magnesium carbonates are soluble in water containing carbonic acid gas. The solubility of chemically precipitated magnesium carbonate in carbonated water is greater than that of calcium carbonate; when these compounds as found in the soil are acted upon by carbonated water, their solubility may be different.

Authorities state that carbonate of lime has a greater solubility than magnesium carbonate as the latter ordinarily exists in nature. According to Hilgard, dolomitic rocks are much more easily decomposed by weathering than the non-magnesian limestones. In some of the soils analyzed it is doubtful whether calcium or magnesium

*Work recently reported by Lyon and Bizzel has shown that calcium is much more abundant than magnesium in soil drainage water and that their ratio is influenced by cropping. Jour. Ind. and Eng. Chem., Vol. III, No. 10.

ever existed as carbonates. The comparative solubility of these two elements combined as silicates is then involved. The relative solubility of calcium and magnesium in soil water is indicated by the amounts contained in spring and well waters; considerable quantities are found in most water supplies even in sections devoid of limestone. Analysis of well water from the Wooster Station farm, the soil of which has no natural carbonates of calcium or magnesium, shows the presence of .067 grams of CaO and .021 grams MgO per liter.

Hopkins[1] states that an average of 90 analyses of Illinois well water, drawn chiefly from glacial sands, gravel or till, shows 330 pounds of calcium and 130 pounds of magnesium in 3 million pounds of water. (About average annual drainage per acre for Illinois).

Data given by Clarke[2] show that in well and spring water and in the water of the rivers of the world, the calcium content is generally in excess of the magnesium.

The crop requirements for these two elements, as indicated by the composition of farm crops, show that calcium is removed in excess of magnesium.

SOIL ACIDITY

Calcium carbonate performs such an important part in the maintenance of soil fertility that, by the action of numerous agencies, the supply is rapidly decreased. The formation of carbonic and other acids, as a natural result of changes taking place in organic matter due to organisms, contributes largely to this loss of lime carbonate from soils. The composition of drainage waters shows that this important soil constituent is removed more abundantly by the percolating soil water than any of the other mineral elements which make up the soil.

Determinations of calcium carbonate residual from applications made to the Wooster soil, which does not contain natural carbonates and is acid in its reaction to litmus paper, give an indication of the rate with which calcium carbonate disappears from cultivated soil.

On a portion of this soil devoted to a fertility experiment, which includes the growing of cereals and sweet clover in a 5-year rotation, ground limestone was applied at the rate of six tons per acre in 1907. This quantity of limestone carried calcium and magnesium carbonates equivalent to 12,000 pounds of calcium carbonate per acre. In 1912 the soil to a depth of eight inches contained only 2,085 pounds; a loss of 9,900 pounds in a period of five years. This means that 82 percent of the calcium carbonate applied has been leached from the soil, or changed by some processes taking place in the soil into forms, other than basic lime compounds,

[1] Univ. of Ill. Agr. Expt. Sta. Soil report No. 4.
[2] The Data of Geochemistry Bul. No. 330 series E. U. S. Geol. Survey.

capable of preventing soil acidity. No calcium carbonate was found in depth of soil below eight inches, to a depth of two feet. A part of the calcium carbonate, carried down by the soil water in solution as calcium bi-carbonate, would react chemically with the minerals present in the lower strata, and the remainder would be carried away into the drainage.

To another part of the farm, used for a 5-year rotation of corn, oats, wheat, clover and timothy, a smaller quantity of lime was applied, and the loss has been distributed over a longer period. The lime treatment here has been as follows: in 1904 caustic lime, which would rapidly change to calcium carbonate in contact with the soil, was applied at the rate of 1,000 pounds per acre; in 1909, the soil was treated with ground limestone at the rate of 2,000 pounds per acre. These amounts of caustic lime and limestone are equivalent to 3, 780 pounds of calcium carbonate. An analysis of this soil, in 1912, showed the presence of only 300 pounds per acre 6 inches of soil, a loss of 92 percent of the quantity originally added. The second depth of soil, 6 to 12 inches, contained only 100 pounds of calcium carbonate per acre.

A deficiency of lime carbonate is indicated by the character of the vegetation and the red color imparted to blue litmus paper.

The fact that leguminous plants which thrive best on calcareous soils can only be grown successfully on acid soils after lime is artificially supplied is sufficient evidence of the necessity of maintaining soils in a neutral or slightly alkaline condition. The degree of acidity, measured by the amount of lime required to change the reaction from acid to neutral, varies considerably for different soils. Sandy soils as a rule have a lower lime requirement than clay soils.

The nature of the acidity, or the cause, is not the same for all soils. Organic matter, in some cases where the drainage is not adequate, is an important factor in the production of acidity. In peat soils or in soils where the organic matter is excessive the presence of organic acids is apparent from the solvent action of the water which drains from the peat on the iron deposits in the sand or gravel through which the water passes. This condition was observed in Lorain county along a sandy ridge three miles east of Amherst, on the farm of H. W. Schmitkons. Here the topography is such that a sandy ridge separates a peat formation on one side from an area on the other which lies so that it receives the drainage from the soil rich in organic matter; the water seeping through the sand formation dissolves iron, which when gradually oxidized gives a characteristic red color to the soil surface on which

it is deposited. In soils which contain scanty supplies of organic materials the acid condition may be due to silicic acid or acid salts of inorganic origin. Cultivated soils develop an increasing acid condition which is indicated by the gradual failure of clover on soils which at one time produced fair yields of this crop and have continued to produce good yields of cereals. This is particularly noticeable on non-calcareous soils where various fertilizing materials, including acid phosphate and ammonium sulphate, were used. The selective absorptive capacity of plants, where different forms of the essential nutrients are supplied, no doubt contributes to an increasing or decreasing degree of acidity.

Nitrogen is assimilated from ammonium sulphate, leaving sulphuric acid in the soil. Where nitrate of soda is applied as a carrier of nitrogen, the crops use the nitrogen furnished, leaving sodium in the soil. The sodium is gradually changed to sodium carbonate, which tends to decrease the acidity. The two carriers of phosphorus, acid phosphate and bone meal, each differ in their effect; acid phosphate adds acid salts to the soil, while where bone meal is used phosphorus, with some calcium, is assimilated by the growing crops, and a portion of the calcium remaining may, under certain conditions, be gradually converted into calcium carbonate.

The growth of clover on the plots of the unlimed Wooster soil treated with acid phosphate and ammonium sulphate, compared with plots where nitrate of soda is used as a carrier of nitrogen, and bone meal as a carrier of phosphorus, serves to illustrate the effect of the relation between the growing crops and the fertilizer used, on the degree of acidity. On the unlimed soil where nitrate of soda furnishes the nitrogen and phosphorus is supplied in bone meal, some clover grows, while on the unlimed soil where acid phosphate and ammonium sulphate are used clover is a complete failure.

The calcium carbonate residual from an application of 3,800 pounds of calcium carbonate to unfertilized soil, and to soil treated with acid phosphate and ammonium sulphate, gives further confirmation of the effect these fertilizing materials have in decreasing the basicity of the soil. Part of the lime was added to the land in 1904 and the rest in 1909. When the soil was examined in 1912, 600 pounds of calcium carbonate per acre were present in the unfertilized soil; 300 pounds in the soil from the acid phosphate plots, and none in the soil where ammonium sulphate was applied as the nitrogen carrier.

The difference between limestone soils and sandstone soils previously referred to shows the deficiency in lime carbonate of the soils from the eastern section of the State.

From the detailed results given in Table II, page 453 and following, will be seen the calcium carbonate expressed in pounds per two million pounds of soil and the reaction to litmus paper.

Comparative tests made in this laboratory on soils have demonstrated that the litmus paper test, if properly made, is a satisfactory qualitative test for the presence or absence of natural lime carbonate. Of the surface soils examined for calcium carbonate and acidity, only five of those which contained calcium carbonate reddened blue litmus paper. Of these five soils two, containing only 100 pounds of calcium carbonate per acre, were virgin timbered soils; one overlaid alkaline subsoil containing calcium carbonate; one, with 400 pounds calcium carbonate per acre, was a virgin timbered soil overlying subsoil containing calcium carbonate; and one, which showed the presence of 600 pounds per acre, was a virgin soil from fence row probably contaminated with dust from limestone road. All of the surface soils that reacted alkaline to red litmus paper contained calcium carbonate.

Treatment with dilute acid is of course a sure indication of carbonates in soils when present in sufficient quantity and not in too finely divided a condition to produce a noticeable effervesence.

Soils from sandstone and shales will, from the nature of their origin, have a greater tendency to be acid than will those from limestone. The detailed results given in Table II point out this fact. Considering the surface soils from Ashtabula, Cuyahoga, Mahoning and Wayne counties, which are not in the limestone area, carbonates were found in amounts equal to 100 parts per 2,000,000 pounds of soil in only two instances, and all the soils with the exception of one were acid in their reaction to litmus paper. With one exception, none of the subsoils from these counties contained calcium carbonate. This one soil, located in Ashtabula county, 2 miles north of Saybrook Corner, Saybrook township, showed the presence of 400 pounds per 2,000,000 pounds of soil in the depth from six inches to three feet.

Dr. Geo. N. Coffey, in charge of the soil survey work of this Station, reports the presence of carbonates, as determined by effervesence with acid, at a depth of three to four feet, in a number of places along roadside cuts, in Wayne, Medina and Cuyahoga counties.

Calcium carbonate was found in considerable amounts in many of the surface soils from the western part of the State, as will be seen from an inspection of the data in Table II. In practically all instances, where the surface soil contained calcium carbonate, the source of the supply was evidenced by the increased amount of calcium carbonate in the corresponding subsoil.

TABLE V. Total and N-5 nitric acid soluble constituents. Surface and subsoils

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Alum-inum Percent	Calcium Percent	Magne-sium Percent	Potas-sium Percent	Phos-phorus Percent	Nitrogen Percent	Humus Percent	Man-ganese Percent
4652	0-6	Gravel..............	Total	33.3500	2.6228	4.9570	.4608	.3927	1.3120	.0663	.1240	1.79	.0480
			Soluble	.0069	.0140	.1447	.0448	.0041	......	.0012	.....	....	.....
4654	0-6	Gravel..............	Total	33.6500	2.4076	5.1070	.3216	.4255	1.3282	.0965	.1813	2.09	.1079
			Soluble	.0104	.0294	.2064	.0394	.0051	......	.0085	.....	....	.....
4709	0-6	Sand	Total	39.3500	1.1953	3.9200	.6445	.2619	1.3200	.0277	.0715	.91	.0094
			Soluble	.0225	.0160	.1174	.0513	.0094	......	.0057	.....	....	.....
4710	6-36	Sand	Total	39.7200	1.2797	3.9500	.6422	.3784	1.4555	.0126	.0255	....	.0049
			Soluble	.0305	.0104	.1176	.0341	.0071	......	.0012	.....	....	.....
4711	0-6	Sand	Total	39.0700	1.1672	3.6800	.7151	.2619	1.3764	.0251	.0650	1.47	.0115
			Soluble	.0211	.0111	.1174	.0542	.0085	......	.0025	.....	....	.....
4665	0-6	Stony loam..........	Total	36.0400	2.2197	4.9800	.2505	.3374	1.5860	.0390	.1260	1.34	.0546
			Soluble	.0054	.0218	.0832	.0601	.0126	......	.0004	.....	....	.....
4666	6-36	Stony loam..........	Total	33.7300	3.8257	6.3600	.2359	.4144	2.1067	.0271	.0542	....	.0155
			Soluble	.0218	.0323	.0916	.0636	.0288	......	.0001	.....	....	.....
4667	0-6	Stony loam..........	Total	36.9400	2.2483	4.6500	.2845	.2932	1.4990	.0450	.1230	1.19	.0694
			Soluble	.0044	.0253	.0674	.0224	.0096	......	.0004	.....	....	.....
4690	0-6	Gravelly loam.......	Total	36.8400	2.1626	4.3700	.3600	.3812	1.5184	.0570	.1180	1.13	.1104
			Soluble	.0093	.0861	.1323	.0406	.0078	......	.0036	.....	....	.....
4691	6-36	Gravelly loam.......	Total	35.2500	3.8828	5.1650	.3138	.5108	1.5795	.0391	.0457	....	.0526
			Soluble	.0164	.0584	.1044	.0229	.0170	......	.0004	.....	....	.....
4670	0-6	Gravelly loam.......	Total	36.5000	2.1199	4.2500	.3405	.4024	1.2895	.1312	.1705	1.82	.0573
			Soluble	.0117	.0812	.2317	.0371	.0075	......	.0005	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoils

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4648	0-6	Gravelly loam.......	Total	33.6100	2.7313	5.8970	.2736	.5371	1.7246	.0504	.1680	1.57	.0779
			Soluble	.0068	.0106	.1178	.0640	.0096	.....	.0003	.....	....	.....
4649	6-36	Gravelly loam.......	Total	31.0100	4.5188	7.9340	.2256	.8685	2.5694	.0311	.0690	....	.0295
			Soluble	.0308	.0403	.1526	.0696	.0306	......	.0001	.....	....	.....
4650	0-6	Gravelly loam.......	Total	32.5700	3.0316	5.6530	.4128	.4594	1.5956	.0566	.1422	1.52	.1005
			Soluble	.0035	.0137	.1069	.0487	.0092	......	.0002	.....	....	.....
4651	0-6	Gravelly loam.......	Total	34.9800	3.0935	4.6510	.4565	.4222	1.2572	.0810	.1157	1.56	.0529
			Soluble	.0115	.0199	.1471	.0605	.0056	......	.0044	.....	....	.....
4722	0-6	Sandy loam	Total	34.4900	2.1698	5.0500	.8480	.3134	1.7809	.0561	.2097	1.72	.0793
			Soluble	.0263	.0080	.0977	.2909	.0292	......	.0019	.....	....	.....
4723	6-36	Sandy loam	Total	32.8709	3.5544	6.1300	.8143	.5222	1.7600	.0384	.0717	....	.0686
			Soluble	.0631	.0558	.1545	.3173	.0447	......	.0023	.....	....	.....
4724	0-6	Sandy loam.........	Total	35.3700	1.6274	4.3500	.7201	.2756	1.8405	.0614	.2255	1.79	.1049
			Soluble	.0162	.0107	.1044	.2358	.0210	......	.0009	.....	....	.....
4701	0-6	Sandy loam.........	Total	34.2700	1.3922	4.9100	1.0550	.4279	1.7455	.0528	.2712	3.35	.0151
			Soluble	.0317	.0279	.2041	.4080	.0405	......	.0172	.....	....	.....
4702	6-36	Sandy loam.........	Total	35.9900	1.8847	5.5100	.8727	.5154	1.7728	.0381	.0645	....	.0204
			Soluble	.0519	.0426	.1553	.2541	.0511	......	.0172	.....	....	.....
4703	0-6	Sandy loam.........	Total	35.3300	1.3640	4.6900	.9320	.4167	1.7295	.0493	.2442	2.63	.0108
			Soluble	.0237	.0551	.1755	.3667	.0357	......	.0117	.....	....	.....
4704	0-6	Sandy loam.........	Total	37.1200	1.2164	4.0800	.9730	.3752	1.4329	.0467	.1830	2.04	.0093
			Soluble	.0166	.0335	.1063	.2600	.0263	.0051	.0137	.....	...	.....
4705	6-36	Sandy loam.........	Total	37.4800	1.5891	4.4600	.8951	.3576	1.5697	.0376	.0487	....	.0145
			Soluble	.0366	.0251	.0622	.1151	.0370	.0020	.0144	.....	....	.....
4688	0-6	Sandy loam.........	Total	38.7400	1.3061	3.7550	.4476	.2745	1.2089	.0277	.1217	1.50	.0102
			Soluble	.0042	.0783	.0921	.0442	.0080	......	.0003	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoils.

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Alum-inum Percent	Calcium Percent	Magne-sium Percent	Potas-sium Percent	Phos-phorus Percent	Nitrogen Percent	Humus Percent	Man-ganese Percent
4689	6-36	Sandy loam.......	Total	39.6200	1.5488	3.8820	.4889	.3314	1.3056	.0135	.0245	....	.0105
			Soluble	.0075	.3106	.0569	.0318	.0123	.....	.0001	.....	....	.....
4658	0-6	Sandy loam.......	Total	34.2600	2.1924	4.3330	.5616	.3490	1.1316	.0575	.1657	1.93	.0188
			Soluble	.0346	.0171	.1954	.0082	.0036	......	.0025	.....	....	.....
4659	6-36	Sandy loam.......	Total	35.9500	2.3807	4.5340	.6864	.4343	1.2572	.0278	.0620	....	.0210
			Soluble	.0298	.0255	.1244	.0079	.0045	......	.0015	.....	....	.....
4660	0-6	Sandy loam.......	Total	32.4200	3.6719	4.7470	.8880	.6102	1.1476	.0558	.1127	1.35	.0750
			Soluble	.0183	.0437	.1475	.0445	.0060	......	.0116	.....	....	.....
4661	0-6	Sandy loam......	Total	31.7300	2.9187	5.2820	.5376	.5294	1.1348	.1100	.1535	1.93	.0313
			Soluble	.0205	.0252	.1455	.0131	.0026	......	.0060	.....	...	.....
4662	0-6	Sandy loam.......	Total	34.6400	2.1789	5.1760	.3504	.4134	1.2863	.0517	.2045	2.12	.0272
			Soluble	.0169	.0227	.0834	.1958	.0146	......	.0024	.....	....	.....
4668	0-6	Sandy loam.......	Total	37.0500	1.9700	4.6500	.3186	.3863	1.4813	.0489	.1125	1.20	.0679
			Soluble	.0058	.0328	.1012	.0342	.0090	......	.0002	.....	....	.....
4669	6-36	Sandy loam.......	Total	35.7300	2.9550	5.4800	.3016	.4664	1.7794	.0301	.0390	....	.0309
			Soluble	.0173	.0223	.0998	.0371	.0265	......	.0003	.....	....	.....
10751	0-6	Sandy loam.......	Total	26.4200	1.9837	4.1360	6.5951	2.7792	1.4830	.0696	.0947	.95	.....
			Soluble	.0646	.0375	.0782	5.4268	1.6866	......	.0088	.....	....	.....
10755	0-6	Sandy loam.......	Total	30.8500	2.1863	4.5532	4.0387	1.2360	1.7860	.1319	.....	....	.....
			Soluble	.0423	.0946	.1177	3.5847	.7919	......	.0967	.....	....	.....
4727	0-6	Sandy loam.......	Total	36.3100	2.0391	5.0000	.4213	.3859	1.7617	.0453	.1902	1.55	.0132
			Soluble	.0180	.0181	.0903	.2659	.0183	......	.0118	.....	....	.....
4728	6-36	Sandy loam..... .	Total	37.0300	4.1700	5.5100	.3067	.6150	1.8568	.0289	.0762	....	.0118
			Soluble	.0239	.0208	.0814	.1879	.0209	......	.0039	.....	....	.....
5279	0-6	Silt loam	Total	36.1800	2.0271	4.6826	.7862	.6083	1.6440	.0592	.1170	1.25	.1454
			Soluble	.0260	.0386	.1262	.1586	.0213	.0064	.0026	.....	....	.....
5280	6-36	Silt loam...... ...	Total	33.7300	3.4545	6.0246	.7493	1.1251	1.9566	.0565	.0582	....	.0554
			Soluble	.0437	.0951	.1682	.1360	.0306	.0074	.0013	....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoils

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
5288	0-6	Silt loam..........	Total	38.0000	1.5607	4.3778	.6448	.5249	1.2508	.0440	.1237	1.85	....
			Soluble	.0117	.0177	.0661	.0675	.0262	.0090	.0007	.....	....	.....
5289	6-36	Silt loam..........	Total	35.3600	2.7294	6.2026	.5033	.5232	1.2186	.0291	.....	....	.....
			Soluble	.0242	.0322	.1208	.0699	.0237	.0102	.0004	.....	....	.....
5294	0-6	Silt loam..........	Total	37.0500	2.1588	4.7219	.1979	.3117	1.2896	.0617	.1395	1.81	.....
			Soluble	.0134	.0182	.0909	.0825	.0140	.0075	.0004	.....	....	.....
5307	0-6	Silt loam..........	Total	36.9700	2.1238	5.0700	.1827	.3007	1.6924	.0334	.0917	1.19	.....
			Soluble	.0117	......	......	.0409	.0104	.0060	.0003	.....	....	.....
10762	0-6	Silt loam..........	Total	36.3700	2.2412	4.3134	.4476	.3577	1.9279	.0944	.1265	....	.....
			Soluble	.0356	.0361	.1776	.2383	.0216	......	.0086	.....	....	.....
4565	0-6	Silt loam..........	Total	35.7700	2.2890	5.2525	.4849	.4060	1.8504	.0579	.1357	2.41	.....
			Soluble	.0204	.0112	.1026	.1357	.0331	......	.0007	.....	....	.....
4566	6-36	Silt loam..........	Total	27.4800	3.6989	6.9579	4.0760	1.8264	1.9792	.0880	.0615	....	.....
			Soluble	.0829	.0815	.2100	3.5012	1.0029	......	.0229	.....	....	.....
4567	0-6	Silt loam..........	Total	36.1600	2.0075	5.4901	.5401	.3937	1.7086	.0367	.1265	1.38	.....
			Soluble	.0235	.0375	.0875	.1522	.0389	......	.0007	.....	....	.....
4568	6-36	Silt loam..........	Total	27.5200	4.4344	7.9343	1.9484	1.6330	1.7794	.0743	.0652	....	.....
			Soluble	.0700	.0532	.1856	.9700	.5239	......	.0069	.....	....	.....
4733	0-6	Silt loam..........	Total	32.5600	2.6121	5.7224	.8961	.4169	1.8794	.0704	.2540	2.49	.0645
			Soluble	.0338	.0064	.1731	.3078	.0399	.....	.0014	.....	....	.....
5286	0-6	Silt loam..........	Total	36.7700	2.2482	4.9462	.4914	.5700	1.3185	.0603	.1465	1.80	.....
			Soluble	.0226	.0462	.1410	.0876	.0196	.0135	.0007	.....	....	.....
5287	6-36	Silt loam..........	Total	35.2700	2.9013	6.0428	.3992	.7312	1.4604	.0345	.0462	....	.....
			Soluble	.0240	.0261	.1138	.0336	.0225	.0082	.0003	.....	....	.....
4744	0-6	Silt loam.........	Total	36.7300	2.0808	4.2340	.4128	.3216	1.8504	.0465	.1085	1.31	.....
			Soluble	.0182	.0140	.0957	.1249	.0237	......	.0010	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoils

Lab. No.	Depth inches	Classification	Total and N-5 HNO₃ Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4745	6-36	Silt loam..........	Total	32.8500	2.6920	6.1906	.3624	.5730	1.9664	.0411	.0522	....	.....
			Soluble	.0309	.0244	.1534	.0944	.0468	......	.0006	.....	....	.....
4746	0-6	Silt loam..........	Total	36.9400	1.8257	4.1435	.3888	.3129	1.8729	.0455	.1322	1.43	.....
			Soluble	.0170	.0230	.0664	.1139	.0276	......	.0013	.....	....	.....
4747	0-6	Silt loam..........	Total	36.0300	2.2016	5.3200	.4330	.4900	1.9213	.0409	.1152	.97	.....
			Soluble	.0160	.0101	.0841	.0876	.0176	......	.0009	.....	....	.....
4748	6-36	Silt loam..........	Total	29.9900	4.4571	8.0700	.7921	.9680	2.2856	.0621	.0690	....	.....
			Soluble	.0529	.0459	.1772	.4436	.1724	......	.0014	.....	....	.....
4749	0-6	Silt loam..........	Total	33.7500	3.2354	5.7800	.7058	.4306	1.8697	.0680	.1517	1.13	.....
			Soluble	.0351	.0165	.1099	.2433	.0763	......	.0014	.....	....	.....
4750	6-36	Silt loam..........	Total	27.3200	4.8933	7.6900	1.7554	1.4601	1.9085	.0557	.0812	....	.....
			Soluble	.0613	.0210	.1674	1.1809	.6544	......	.0011	.....	....	.....
4751	0-6	Silt loam..........	Total	36.8200	2.0004	3.9105	.5984	.3294	1.8053	.0395	.1257	.98	.....
			Soluble	.0164	.0426	.0642	.1502	.0376	......	.0008	.....	....	.....
5081	0-6	Silt loam..........	Total	36.1100	2.3483	4.9641	.4865	.4255	1.8923	.0373	.0765	.47	.0439
			Soluble	.0387	.0391	.1222	.1491	.0379	......	.0029	.....	....	.....
5082	6-36	Silt loam..........	Total	33.4000	3.5688	6.0779	.4841	.5710	2.0019	.0352	.0460	....	.0513
			Soluble	.0594	.0470	.1333	.1651	.0689	......	.0001	.....	....	.....
5083	0-6	Silt loam..........	Total	36.2400	1.6416	4.1260	.6276	.3861	1.7891	.0567	.1817	1.34	.0570
			Soluble	.0274	.0694	.0867	.2609	.0634	.....	.0138	.....	....	.....
5284	0-6	Silt loam..........	Total	35.8600	2.2688	5.4100	.5528	.5946	1.5440	.0678	.1482	1.40	.....
			Soluble	.0193	.0101	.1166	.1150	.0158	.0093	.0007	.....	....	.....
5285	6-36	Silt loam..........	Total	34.1700	3.3894	6.4491	.4576	.7847	1.6892	.0320	.0472	....	.....
			Soluble	.0418	.0350	.1448	.0744	.0381	.0097	.0003	.....	...	.....
5293	0-6	Silt loam..........	Total	35.0100	2.3444	5.5189	.2813	.3281	1.7086	.0770	.1790	1.79	.....
			Soluble	.0221	.0306	.1106	.1420	.0247	.0094	.0002	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
10769	0-6	Silt loam..........	Total	32.3400	2.2688	5.3767	.8508	.5972	1.7891	.1068	.....	....	.....
			Soluble	.0531	.0375	.1795	.4481	.0908	......	.0054	.....	....	.....
10770	0-6	Silt loam..........	Total	30.1800	2.5369	5.5212	.9492	.6256	1.8794	.0596	.....	....	.....
			Soluble	.0451	.0645	.2258	.4150	.0670	......	.0055	.....	....	.....
10771	0-6	Silt loam..........	Total	32.0600	2.4750	5.7164	.8705	.6257	1.8246	.0717	.....	....	.....
			Soluble	.0542	.0412	.1754	.3225	.0744	......	.0059	.....	....	.....
10772	0-6	Silt loam..........	Total	31.4000	2.3305	5.5434	.9246	.6158	1.8536	.0793	.....	....	.....
			Soluble	.0528	.0646	.2120	.4900	.0686	......	.0085	.....	....	.....
10732	0-6	Silt loam..........	Total	37.0900	1.6638	4.5509	.5609	.4474	1.8246	.0288	.0925	....	.....
			Soluble	.0244	.0328	.0421	.1426	.0247	......	.0031	.....	....	.....
4679	0-6	Silt loam..........	Total	36.5200	1.9641	4.6460	.2509	.3461	1.7102	.0504	.1330	1.62	.1321
			Soluble	.0075	.0132	.1069	.0495	.0121	......	.0004	.....	....	.....
4675	0-6	Silt loam..........	Total	36.2600	1.8415	4.7150	.3190	.3734	1.6890	.0406	.1225	1.50	.1359
			Soluble	.0082	.0099	.0910	.0589	.0130	......	.0002	.....	....	.....
4676	6-36	Silt loam..........	Total	34.7700	3.4472	5.4890	.2942	.5265	1.7939	.0343	.0480	....	.0648
			Soluble	.0178	.0195	.0654	.0619	.0305	......	.0001	.....	....	.....
4677	0-6	Silt loam..........	Total	36.6700	1.8700	4.7150	.2553	.3127	1.6118	.0391	.1227	1.62	.1291
			Soluble	.0061	.0099	.0883	.0300	.0069	......	.0003	.....	....	.....
4673	0-6	Silt loam..........	Total	37.0300	1.9128	4.6560	.2699	.3773	1.7069	.0403	.1005	1.20	.0949
			Soluble	.0082	.0058	.1008	.0483	.0103	.....	.0015	.....	....	.....
4674	0-6	Silt loam..........	Total	36.2200	1.8272	4.4340	.3405	.3499	1.6892	.0543	.1537	2.17	.1158
			Soluble	.0069	.0226	.0921	.0849	.0195	......	.0024	.....	....	.....
4644	0-6	Silt loam..........	Total	31.9000	3.0030	6.1150	.3048	.5906	1.8729	.0494	.2140	2.02	.0798
			Soluble	.0088	.0124	.1817	.1291	.0136	.....	.0003	.....	....	.....
4645	6-36	Silt loam..........	Total	30.8590	4.3329	7.4300	.2544	.8739	2.4693	.0298	.0670	....	.0327
			Soluble	.0411	.0610	.1529	.1107	.0420	......	.0002	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
10756	0-6	Silt loam..........	Total	38.2300	1.5537	3.9960	.3394	.3052	1.4379	.0428	.1190	....	....
			Soluble	.0246	.0050	.0997	.0710	.0116	.....	.0001	.....	....	....
10734	0-6	Silt loam..........	Total	36.1900	1.7876	5.4456	.4700	.6235	1.8697	.0360	.1207	....	....
			Soluble	.0603	.0428	.2136	.0995	.0260	......	.0103	.....	....	....
10736	0-6	Silt loam..........	Total	36.0300	1.5744	4.5934	.5707	.6267	1.7860	.0403	.....	....	....
			Soluble	.0102	.0398	.0840	.1581	.0327	......	.0015	.....	....	....
10737	0-6	Silt loam..........	Total	36.2000	2.2138	5.1753	.5265	.7558	1.8440	.0290	.0910	....	....
			Soluble	.0267	.0272	.0791	.1250	.0383	......	.0007	.....	....	....
10739	0-6	Silt loam..........	Total	36.3300	1.8357	4.7507	.5166	.4496	1.8279	.0482	.1437	....	....
			Soluble	.0238	.0364	.0875	.1980	.0345	......	.0024	.....	....	....
10743	0-6	Silt loam..........	Total	33.6300	2.5438	5.4170	.5068	.6738	2.1600	.0674	.1995	....	....
			Soluble	.0302	.0238	.1234	.1925	.0362	......	.0044	.....	....	....
10763	0-6	Silt loam..........	Total	35.4200	1.8700	4.5551	.5508	.3938	1.8182	.0617	.2025	....	....
			Soluble	0194	.....	......	.1915	.0157	......	.0009	.....	....	....
10746	0-6	Silt loam..........	Total	35.1900	2.1107	5.2905	.4822	.5655	1.8698	.0427	.1537	....	....
			Soluble	.0192	.0182	.1080	.1520	.0248	......	.0007	.....	....	....
10753	0-6	Silt loam..........	Total	37.2600	1.3610	4.1804	.3394	.3599	1.5893	.0590	.....	....	....
			Soluble	.0235	.0333	.1145	.1220	.0228	......	.0016	.....	....	....
10754	0-6	Silt loam..........	Total	37.1600	1.3750	4.1539	.3344	.3249	1.5538	.0532	.....	....	....
			Soluble	.0227	.0367	.1194	.1225	.0164	......	.0012	.....	....	....
10757	0-6	Silt loam..........	Total	38.0600	1.5399	4.0848	.2754	.2931	1.3927	.0352	.1050	....	....
			Soluble	.0148	.0521	.0989	.0687	.0126	......	.0004	.....	....	....
10760	0-6	Silt loam..........	Total	36.8400	1.9662	4.4132	.3049	.3850	1.8955	.0621	.1050	....	....
			Solnble	.0251	.0168	.0759	.0933	.0156	......	.0012	.....	....	....
10761	0-6	Silt loam..........	Total	33.0600	2.4613	5.1039	.6392	.5062	1.9214	.0754	.2365	....	....
			Soluble	.0338	.0227	.1476	.3030	.0387	......	.0017	.....	....	....
4646	0-6	Silt loam..........	Total	34.2600	2.3032	5.4040	.2640	.4845	1.5795	.0373	.1960	1.71	.0273
			Soluble	.0048	.0350	.1382	.1227	.0118	......	.0003	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
5401-1	0-6	Silt loam..........	Total	32.3100	2.9975	7.1484	.3295	.4386	1.8536	.0618	.0674	....	.....
			Soluble	.0226	.0207	.1197	.1760	.0139	......	.0011	.....	....	.....
5401-2	6-36	Silt loam..........	Total	30.6900	3.8431	8.8023	.3000	.5447	2.1953	.0558	.0363	....	.....
			Soluble	.0438	.0493	.1442	.1915	.0287	......	.0012	.....	....	.....
5283	0-6	Silt loam..........	Total	32.2900	2.4338	5.3298	1.7505	.9625	2.0694	.2805	.2582	2.21	.0980
			Soluble	.0648	.2244	.2603	.5145	.0411	.0107	.1209	.....	....	.....
4647	0-6	Silt loam..........	Total	35.4100	2.4453	5.1500	.1872	.4900	1.4958	.0482	.1407	1.38	.0257
			Soluble	.0031	.0165	.1233	.0280	.0061	......	.0006	.....	....	.....
10738	0-6	Clay loam.........	Total	27.4300	2.7402	5.4567	4.2300	2.2236	1.7601	.0647	.1660	....	.....
			Soluble	.0377	.0244	.1436	2.8400	1.4350	......	.0105	.....	....	.....
10740	0-6	Clay loam.........	Total	30.5300	2.7552	6.3650	.9693	.7296	1.8956	.0904	.2740	....	.....
			Soluble	.0721	.0428	.2542	.4075	.2144	......	.0118	.....	....	.....
4680	0-6	Clay loam.........	Total	36.3400	2.2198	4.9480	.2675	.3931	1.6408	.0346	.1137	1.24	.1118
			Soluble	.0093	.0027	.0989	.0577	.0129	......	.0002	.....	....	.....
4671	0-6	Clay loam.........	Total	32.8900	3.2110	6.4200	.2529	.5665	1.9987	.0558	.1672	1.50	.0521
			Soluble	.0140	.0251	.1464	.1114	.0156	......	.0003	.....	....	.....
4672	6-36	Clay loam.........	Total	34.3400	3.1756	6.2400	.2359	.5277	1.9567	.0325	.0670	....	.0410
			Soluble	.0122	.0223	.1163	.0459	.0123	......	.0001	.....	....	.....
4712	0-6	Clay loam.........	Total	33.9600	2.2697	5.4730	.6155	.5322	1.9761	.0385	.1577	1.96	.0921
			Soluble	.0411	.0512	.1331	.2376	.0661	......	.0014	.....	....	.....
4713	6-36	Clay loam.........	Total	27.8000	4.0256	7.7800	2.1893	1.2174	2.7304	.0317	.0650	....	.0493
			Soluble	.1445	.1902	.2450	1.9696	.4156	......	.0062	.....	....	.....
4714	0-6	Clay loam.........	Total	33.2600	2.2126	3.3250	.9584	.5802	1.8471	.0481	.2122	1.23	.0660
			Soluble	.0505	.1007	.1209	.6427	.1728	......	.0024	.....	....	.....
10735	0-6	Clay loam.........	Total	28.2900	3.1488	6.5293	.9299	.9899	2.0600	.1222	.....	....	.....
			Soluble	.0524	.0874	.2318	.5560	.0488	......	.0063	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
10764	0-6	Clay loam.........	Total	29.8600	4.3175	7.0973	1.1456	.8674	2.4500	.1334	.1030	....	.....
			Soluble	.0726	.0924	.1971	.7650	.1449	......	.0250	.....	....	.....
10733	0-6	Clay loam.........	Total	30.8000	2.7844	6.3960	.9446	.7985	2.1726	.0953	.2580	....	.....
			Soluble	.0143	.0213	.0852	.0995	.0266	......	.0010	.....	....	.....
4752	0-6	Clay loam.........	Total	36.1400	2.4840	4.9852	.9299	.3194	1.9698	.0397	.1037	.91	.0779
			Soluble	.0242	.0173	.1021	.4013	.0227	......	.0004	.....	....	.....
4753	6-36	Clay loam.........	Total	32.4200	3.8684	6.4648	.4427	.6300	2.1792	.0468	.0540	....	.0525
			Soluble	.0505	.0475	.1470	.1604	.0531	......	.0005	.....	....	.....
4639	0-6	Clay loam.........	Total	34.6400	2.4167	5.5012	.2736	.5331	1.6602	.0584	.2060	2.40	.....
			Soluble	.0091	.0180	.1637	.0803	.0168	.0198	.0013	.....	....	.....
4640	0-6	Clay loam.........	Total	35.4100	2.1593	5.3991	.2640	.6016	1.5860	.0454	.1795	1.88	.....
			Soluble	.0089	.0101	.1515	.0768	.0118	.0108	.0005	.....	....	.....
4641	0-6	Clay loam.........	Total	34.4400	2.3452	5.6810	.3264	.5331	1.5602	.0559	.2030	1.74	.....
			Soluble	.0107	.0165	.1429	.1417	.0203	.0115	.0004	.....	....	.....
4642	0-6	Clay loam.........	Total	35.6900	2.1021	5.3347	.2592	.5030	1.5602	.0411	.1695	2.50	.....
			Soluble	.0088	.0291	.1397	.0831	.0143	.0129	.0003	.....	....	.....
4643	0-6	Clay loam.........	Total	34.9800	2.3166	5.5389	.2568	.5793	1.5570	.0538	.1945	1.96	.....
			Soluble	.0081	.0137	.1533	.0813	.0173	.0105	.0004	.....	....	.....
4663	0-6	Clay loam.........	Total	34.7300	2.4910	5.2700	.3356	.5589	1.6408	.0382	.1425	1.61	.0557
			Soluble	.0089	.0166	.0903	.0825	.0103	......	.0001	.....	....	.....
4664	6-36	Clay loam.........	Total	31.1600	4.0970	7.2400	.3454	.5911	2.4048	.0321	.0672	....	.0250
			Soluble	.0406	.0542	.1411	.1326	.0459	......	.0004	.....	...	.....
4681	0-6	Clay loam.........	Total	36.7100	2.0556	4.6880	.3406	.3725	1.5441	.0393	.1372	1.18	.1220
			Soluble	.0089	.0181	.1032	.0707	.0112	......	.0001	.....	....	.....
4682	6-36	Clay loam.........	Total	34.6900	3.1834	5.8070	.3406	.5294	1.8374	.0221	.0550	....	.0586
			Soluble	.0204	.0163	.1067	.0672	.0279	......	.0001	.....	....	.....
4683	0-6	Clay loam.........	Total	36.3900	1.9342	4.4020	.4281	.3467	1.4829	.0443	.1642	1.61	.1058
			Soluble	.0101	.0205	.1218	.1203	.....	......	.0002	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
5085	0-6	Clay loam........	Total	36.7900	1.7016	4.2300	.4865	.2789	1.6424	.0928	.1125	1.09	.0506
			Soluble	.0138	.0376	.0690	.1627	.0274	.....	.0008	.....	....	.....
5086	6-36	Clay loam.......	Total	32.8700	3.7187	5.9500	.4037	.4413	1.8245	.0211	.0632	....	.0208
			Soluble	.0354	.0330	.0896	.1887	.0658	......	.0013	.....	....	.....
4733	0-6	Clay loam........	Total	36.5500	2.0320	4.5600	.4037	.3140	1.6755	.0393	.1437	1.28	.0746
			Soluble	.0138	.0317	.0779	.1515	.0134	......	.0005	.....	....	.....
4734	0-6	Clay loam.........	Total	36.8600	2.0321	4.6100	.4086	.3171	1.7664	.0343	.1075	1.01	.0731
			Soluble	.0108	.0110	.0783	.1008	.0186	......	.0003	.....	....	.....
4735	6-36	Clay loam........	Total	32.8500	4.1558	6.8600	.3234	.5769	2.2162	.0346	.0700	...	.0421
			Soluble	.0284	.0317	.1163	.0890	.0418	......	.0002	.....	....	.....
4730	0-6	Clay loam.........	Total	33.4200	2.4265	5.3352	.7457	.5427	1.9566	.0668	.2210	1.93	.0987
			Soluble	.0263	.0335	.1136	.2583	.0678	......	.0011	.....	....	.....
4731	6-36	Clay loam.........	Total	29.4800	3.7114	6.6929	2.3326	1.3015	2.4050	.0482	.0847	....	.0465
			Soluble	.0817	.1189	.1216	1.6754	.3937	......	.0049	.....	....	.....
4732	0-6	Clay loam........	Total	33.9600	2.4265	5.6269	.5963	.4566	2.1536	.0475	.2837	1.79	.0487
			Soluble	.0213	.0361	.1172	.1816	.0371	......	.0012	.....	....	.....
4719	0-6	Clay loam.........	Total	31.7100	3.3761	6.6400	.3867	.5282	2.4193	.0543	.1702	1.61	.0606
			Soluble	.0211	.0503	.1142	.1029	.0510	......	.0008	.....	....	.....
4720	6-36	Clay loam.........	Total	30.0200	4.0541	7.8000	.3129	.7300	2.7511	.0327	.0767	....	.0447
			Soluble	.0613	.0726	.1267	.2423	.0671	......	.0007	.....	....	.....
4721	0-6	Clay loam.........	Total	31.6400	3.0556	5.9800	.6422	.6771	2.2709	.0698	.2357	1.44	.0914
			Soluble	.0284	.0636	.1093	.2709	.0545	......	.0013	.....	....	.....
10766	0-6	Clay loam.........	Total	30.4500	3.8775	5.5879	1.0132	.7164	1.8827	.0757	.....	....	.....
			Soluble	.0522	.0392	.1843	.5266	.1395	......	.0011	.....	....	.....
10767	0-6	Clay loam.........	Total	35.0400	2.3099	5.3942	.5164	.5031	2.2114	.0414	.1280	....	.....
			Soluble	.0251	.0238	.0825	.1400	.0292	......	.0012	.....	....	.....
10768	0-6	Clay loam.........	Total	35.2500	1.9731	5.0883	.4721	.4463	2.1116	.0398	.1397	....	.....
			Soluble	.0190	.0350	.1022	.1000	.0253	.....	.0009	....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4684	0-6	Clay loam	Total	35.1400	2.2412	5.2980	.3698	.3883	1.6086	.0510	.1642	1.57	.0422
			Soluble	.0117	.0657	.1285	.1037	.0217	......	.0004	.....	....	.....
4740	0-6	Clay loam	Total	36.4300	2.2462	4.4000	.4368	.3216	1.5152	.0675	.1420	1.27	.....
			Soluble	.0157	.0188	.0836	.1940	.0144	......	.0100	.....	....	.....
5281	0-6	Clay loam	Total	28.2600	3.8500	7.1060	2.8133	2.0125	2.7916	.3058	.1922	1.50	.1136
			Soluble	.1583	.2949	.3755	.9649	.1055	.0116	.1279	.....	....	.....
5282	6-36	Clay loam	Total	25.9800	3.9470	8.3260	2.3957	1.4054	3.2108	.3114	.....	....	.0999
			Soluble	.2835	.6044	.4576	1.7923	.2143	.0084	.1621	.....	....	.....
10750	0-6	Clay loam.........	Total	35.2200	2.6607	4.8398	.5462	.3664	1.7924	.0647	.1357	....	.....
			Soluble	.0552	.0465	.1514	.2028	.0526	......	.0066	.....	....	.....
5087	0-6	Black clay........	Total	29.1600	2.4891	5.9800	1.3499	.5331	1.2685	.0980	.3467	3.26	.0223
			Soluble	.0857	.0423	.2963	1.0143	.1432	.....	.0242	.....	....	.....
5086	6-36	Black clay	Total	26.2400	3.1712	4.5400	5.1033	2.4222	1.2991	.0517	.....	....	.0232
			Soluble	.1278	.0278	.1340	4.8002	1.7980	......	.0208	.....	....	.....
4725	0-6	Sandy clay........	Total	32.1300	1.1592	5.3300	.6841	.3346	1.8519	.0716	.1925	1.80	.0891
			Soluble	.0371	.0549	.1049	.2816	.0365	......	.0020	.....	....	.....
4726	6-36	Sandy clay........	Total	33.8000	1.0547	5.6700	.7076	.2728	1.9453	.0462	.0987	....	.0676
			Soluble	.0446	.0604	.1024	.2387	.0430	......	.0016	.....	....	.....
4741	0-6	Black clay loam ..	Total	25.9000	4.0006	5.0188	1.3200	.6650	1.3120	.1094	.6625	6.48	.....
			Soluble	.0608	.1641	......	1.0600	.1914	......	.0054	.....	....	.....
4742	6-36	Black clay loam	Total	31.4600	2.4769	6.2265	1.0464	.8575	1.8181	.0323	.0970	....	.....
			Soluble	.0767	.0599	.1961	.6200	.2560	......	.0132	.....	....	.....
4743	0-6	Black clay loam ..	Total	24.9900	2.9468	2.2490	2.4672	.8673	1.5087	.1293	.8322	6.56	.....
			Soluble	.0835	.2618	.2076	2.0400	.4813	.....	.0160	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4737	0-6	Black clay loam ..	Total	29.7100	3.2205	5.4700	.9146	.7546	1.7955	.0790	.3145	3.15	.0336
			Soluble	.0607	.0811	.1813	.5902	.0896	......	.0053	.....	....	.....
4738	6-36	Black clay loam ..	Total	31.3600	3.9798	6.0900	.7126	.5933	1.9421	.0625	.1137	...	.1221
			Soluble	.0700	.0601	.1618	.4399	.0955	......	.0079	.....	....	....
4739	0-6	Black clay loam ..	Total	28.8200	3.2205	5.6800	.9901	.6809	1.7455	.0696	.4230	3.49	.0189
			Soluble	.0682	.0969	.2138	.7329	.1204	......	.0053	.....	....	.....
10744	0-6	Black clay loam ..	Total	29.7900	2.4888	6.2848	1.0627	.8586	1.8312	.0687	.3325	....	.....
			Soluble	.0571	.0835	.2239	.4950	.1094	.....	.0084	.....	....	.....
10745	0-6	Black clay loam ..	Total	28.1900	2.9838	7.1307	1.0283	.9538	2.2050	.1165	.3662	....	.....
			Soluble	.0771	.0910	.2748	.5525	.0892	......	.0151	.....	....	.....
4754	0-6	Black clay loam ..	Total	30.2100	3.0121	5.6534	.9876	.6497	1.7891	.0743	.3077	3.09	.0823
			Soluble	.0763	.0307	.2445	.6383	.1296	......	.0019	.....	....	.....
4755	0-6	Black clay loam ..	Total	29.8200	2.8907	5.2080	1.8292	.8750	1.7278	.0651	.2980	2.84	.0692
			Soluble	.0592	.0652	.0872	1.4388	.4976	......	.0011	....	....	.....
4716	0-6	Black clay loam ..	Total	30.4200	2.9769	6.5600	.8360	.7033	2.4080	.0974	.1980	2.09	.0297
			Soluble	.0592	.1231	.2439	.4224	.0667	.0104	.0138	.....	....	.....
4717	6-36	Black clay loam ..	Total	31.1800	2.3767	6.8100	.6941	.5250	2.4336	.0847	.1245	....	.0585
			Soluble	.0681	.1346	.2450	.3645	.0807	.0124	.0147	.....	....	.....
4718	0-6	Black clay loam ..	Total	27.9100	3.6279	6.8400	.7233	.5550	2.4756	.1173	.3732	3.24	.0560
			Soluble	.0474	.1340	.2330	.4253	.0694	.0207	.0075	.....	...	.....
14163	0-6	Black clay loam ..	Total	....	......	......	1.0440	.....	2.0240	.1010	.4010	4.27	.....
			Soluble	....	......	......	.7360	.....	.0110	.0170	....	....	.....
4715	0-6	Clay	Total	30.3500	3.5474	7.1600	.4209	.8209	2.9367	.0603	.2145	2.02	.0767
			Soluble	.0385	.0649	.1924	.1421	.0698	......	.0006	.....	....	.....
4699	0-6	Clay	Total	36.0400	2.1165	5.3900	.4653	.5039	2.0325	.0544	.1223	1.21	.0616
			Soluble	.0220	.0559	.1076	.1014	.0339	......	.0041	.....	....	.....

TABLE V.—Concluded. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4700	6-36	Clay	Total	30.8700	2.9904	7.6400	.4666	.9264	2.6722	.0402	.0610	....	.0380
			Soluble	.0794	.1091	.2503	.1226	.0995	......	.0013	.....	....	.....
4667	0-6	Clay	Total	29.8700	4.4654	6.9420	.3120	.4539	1.9664	.0659	.2525	2.40	.1258
			Soluble	.0150	.0215	.1735	.1367	.0278	......	.0004	.....	....	.....
4685	0-6	Clay	Total	25.4200	4.1112	9.2010	.4330	.6792	2.0567	.0964	.3430	3.44	.0615
			Soluble	.0359	.1840	.2275	.2883	.0540	......	.0023	.....	....	.....
4686	6-36	Clay	Total	33.7500	2.7480	6.6120	.3016	.5272	1.8310	.0688	.0927	....	.0163
			Soluble	.0270	.4905	.1522	.1061	.0189	......	.0122	.....	....	.....
4687	0-6	Clay	Total	36.7300	2.0484	4.7620	.2554	.3330	1.4442	.0424	.1322	1.53	.0502
			Soluble	.0084	.0889	.1098	.0707	.0121	......	.0002	....	....	....
4696	0-6	Clay	Total	32.2300	3.2910	5.6000	.9706	.6349	2.1582	.0656	.2547	2.31	.0535
			Soluble	.0516	.0650	.1553	.3491	.0436	......	.0053	.....	..	.....
4697	6-36	Clay	Total	32.1700	3.2910	6.8400	.7090	.8430	2.3936	.0394	.0677	....	.0417
			Soluble	.0624	.0748	.1156	.3526	.0747	.....	.0063	.....	....	.....
4698	0-6	Clay	Total	31.3600	2.7563	6.2200	1.0514	.8406	2.1967	.0498	.2230	1.88	.0351
			Soluble	.0606	.0657	.1071	.7559	.2143	......	.0077	....	....	.....
4706	0-6	Clay	Total	31.4100	2.1025	5.4500	1.0263	.5244	1.8503	.0781	.3272	3.39	.0129
			Soluble	.0639	.0489	.1999	.3536	.0617	.....	.0202	.....	....	.....
4707	6-36	Clay	Total	33.4800	2.9884	5.9300	.7605	.6053	2.0163	.0622	.0670	....	.0580
			Soluble	.0909	.0636	.1569	.2171	.0919	......	.0192	.....	....	.....
4708	0-6	Clay	Total	33.6500	1.9266	5.1400	.8681	.4107	1.7181	.0632	.2820	2.88	.0354
			Soluble	.0335	.0419	.1431	.2533	.0569	......	.0044	.....	....	.....
4655	0-6	Clay	Total	31.0900	1.1567	7.0060	.2556	.3697	1.7214	.0504	.3190	3.54	.0063
			Soluble	.0127	.0263	.3349	.0817	.0179	......	.0044	.....	....	.....
4656	6-36	Clay	Total	31.1100	4.1157	7.5790	.4056	.7591	2.2886	.0417	.0675	....	.0183
			Soluble	.0892	.0849	.2417	.2673	.0485	......	.0095	.....	....	.....

METHOD USED FOR DETERMINING CARBONATES

While the analytical methods employed in the work are outlined in the addenda, special attention is directed to the method used in determining carbonates, for the reason that the results obtained by the method in general use give inaccurate and misleading results concerning the calcium carbonate content of soils. Determinations made by the Official method,[1] boiling soils at 100° C. with dilute acid, showed no correlation between the calcium carbonate found and the soil's reaction with litmus paper or the Veitch qualitative test.

For many of the acid surface soils examined, the Official method indicated the presence of 3,000 pounds of calcium carbonate per 2,000,000 pounds of soil; a much larger quantity than was found in other soils which gave an alkaline reaction with red litmus paper. These differences between calcium carbonate found and the soil reaction were especially marked in the case of soils containing fairly large amounts of organic matter. These facts led to the adoption of the method devised by F. S. Marr while connected with the Rothamsted Experiment Station.[2]

The essential feature of the method is treating the soil with very dilute acid at 50°C., and under reduced pressure. This procedure eliminates the error due to the decomposing organic matter and liberation of carbon dioxide other than that from inorganic carbonates. Table VI, page 491, gives a comparison of the carbon dioxide obtained by the two methods and the soil reaction for a large number of the soils included in this work.[3]

PHOSPHORUS

Only fourteen, of the hundred and twenty-six surface soils examined, contained more than 0.10 percent of phosphorus. The highest percent of phosphorus, 0.30 percent, was found in soil from an alfalfa field located near Madisonville, Hamilton county. Other soils from this vicinity, which have been examined with respect to their phosphorus supply, show a larger amount than the average for soils throughout the State. The agency causing the increased accumulation of phosphorus in some soils from this particular area has probably been a continuation of the geological formation, carrying tri-calcium phosphate, found in Tennessee and which extends north through part of Kentucky. Evidence of this is given by the analysis, made in this laboratory, of soil from the farm of the Kentucky Experiment Station; 0.45 percent of phosphorus was found in the surface six inches and 0.52 percent in the depth from six to eighteen inches.

[1]Bul. 107, Bureau of Chemistry, U. S. Department of Agriculture.
[2]Jour. Agr. Science, Vol. III, part 2.
[3]For a more detailed presentation of results obtained in this laboratory in connection with this work, see article in the Jour. of Ind. and Engineering Chemistry, Vol. 5, No. 2, 1912, "A Comparison of Some Qualitative and Quantitative Methods for Carbonates in Soil," by E. W. Gaither.

TABLE VI.—Part 1. Surface soils 0-6 inches that redden blue litmus paper

Lab. No.	Veitch test	Litmus test	Percent CO_2 by Marr method	Percent CO_2 by official method	Percent Humus	Condition	Class
4688	Acid	Acid	0	0.0242	1.50	C.	Sandy loam
5081	"	"	0	0.0308	0.47	C.	Silt loam
4687	Sl. Alk.	Sl. Acid	0	0.0308	1.53	P.	Clay
4709	Acid	Sl. Acid	0	0.0341	0.91	C.	Sand
4677	"	Acid	0	0.0352	1.62	C.	Silt loam
4681	"	"	0	0.0440	1.18	C.	Clay loam
4680	"	Sl. Acid	0	0.0460	1.24	C.	Clay loam
4711	"	"	0	0.0462	1.47	V. F. R.	Sand
4734	Sl. Alk.	"	0	0.0462	1.01	C.	Clay Loam
4651	Acid	Acid	0	0.0484	1.56	M.	Gravelly loam
4652	"	"	0	0.0484	1.79	M.	Gravel
4668	"	"	0	0.0484	1.20	C.	Sandy loam
4673	Sl. Alk.	Sl. Acid	0	0.0484	1.20	C.	Silt loam
4719	Acid	Acid	0	0.0506	1.61	C.	Clay loam
4650	"	Sl. Acid	0	0.0506	1.52	V. M. G.	Gravelly loam
4727	Sl. Alk.	Neutral	0	0.0550	1.55	C.	Sandy loam
4655	Acid	Acid	0	0.0572	3.54	C.	Clay
4663	"	"	0	0.0572	1.61	C.	Clay loam
4690	"	"	0	0.0572	1.13	C.	Gravelly loam
4640	Sl. Alk.	"	0	0.0594	1.88	C.	Clay loam
4671	"	Sl. Acid	0	0.0594	1.50	C.	Clay loam
4684	Acid	Acid	0	0.0594	1.57	C.	Clay loam
4642	"	"	0	0.0616	2.50	C.	Clay loam
4643	"	"	0	0.0616	1.96	C.	Clay loam
4661	"	"	0	0.0616	1.93	C.	Sandy loam
4704	"	Sl. Acid	0	0.0660	2.04	C.	Sandy loam
4699	"	Acid	0	0.0680	1.21	C.	Clay

Sl.=slightly. St.=strongly. Alk.=alkaline. C.=cultivated. P.=pasture. V. F. R.=virgin fence row. M.=meadow. V. O. W.=virgin open woodland R.=road side. V. P. virgin pasture. P.=pasture. V. M. G.=virgin maplegrove.

TABLE VI. Part 1.—Continued. Surface soils 0-6 inches that redden blue litmus paper

Lab. No.	Veitch test	Litmus test	Percent CO_2 by Marr method	Percent CO_2 by official method	Percent Humus	Condition	Class
4660	Acid	Sl. Acid	0.0022	0.0682	1.35	V. O. W	Sandy loam
4639	"	Acid	0	0.0682	2.40	C.	Clay loam
4662	"	"	0	0.0682	2.12	M.	Sandy loam
4641	"	"	0	0.0682	1.74	C.	Clay loam
5279	"	"	0	0.0704	1.25	C.	Silt loam
4675	"	Sl. Acid	0	0.0704	1.50	C.	Silt loam
4696	"	"	0	0.0715	2.31	C.	Clay
4665	Sl. Alk.	Acid	0	0.0726	1.34	C.	Stony loam
4732	"	Sl. Acid	0	0.0748	1.79	M.	Clay loam
4647	Acid	Acid	0	0.0770	1.38	M.	Silt loam
4654	"	"	0	0.0770	2.09	C.	Gravel
4658	Alk.	"	0	0.0770	1.93	C.	Sandy loam
4679	Acid	"	0	0.0792	1.62	M.	Silt loam
4733	Sl. Alk.	Sl. Acid	0	0.0814	2.49	C.	Silt loam
4674	Acid	"	0	0.0814	2.17	V. F. R.	Silt loam
4715	"	"	0	0.0836	2.02	V. O. W.	Clay
4736	"	"	0	0.0902	1.28	V. O. W.	Clay loam
4670	"	Acid	0	0.0902	1.82	C.	Gravelly loam
4648	"	"	0	0.0946	1.57	C.	Gravelly loam
4703	"	Sl. Acid	0	0.0957	2.63	V. O. W.	Sandy loam
4644	"	Acid	0	0.0990	2.02	M.	Silt loam
4657	Sl. Alk.	"	0	0.1012	2.40	V. O. W.	Clay
4721	Acid	Sl. Acid	0.0132	0.1034	1.44	R. V. F. R.	Clay loam
4683	"	Acid	0	0.1078	1.61	V. O. W.	Clay loam
5283	"	"	0	0.1100	2.21	V. P.	Silt loam
4685	"	"	0	0.1100	3.44	C.	Clay
4646	"	"	0	0.1166	1.71	V. O. W.	Silt loam
4706	"	Sl. Acid	0	0.1188	3.39	V. O. W.	Clay
4718	"	Acid	0.0022	0.1320	3.24	V. O. W.	Black clay loam
4737	Alk.	Neutral	0	0.1518	3.15	C.	Black clay loam

Average 0.0714 percent CO_2 = 3244 pounds $CaCO_3$ per acre, 7 inches by official method.

TABLE VI.—Part 2. Surface soils 0-6 inches that turn red litmus paper blue.

Lab. No.	Veitch test	Litmus test	Percent CO_2 by Marr method	Percent CO_2 by official method	Difference	Percent humus	Condition	Class
4708	Acid	Sl. Alk.	0.0011	0.1122	0.1111	2.88	V. O. W.	Clay
4667	"	Alk.	0.0022	0.0726	0.0704	1.19	V. O. W.	Stony loam
4747	Sl. Alk.	V. Sl. Alk.	0.0033	0.0440	0.0407	0.97	C.	Silt loam
4722	Alk.	Alk.	0.0044	0.0902	0.0858	1.72	C.	Sandy loam
4740	"	Neutral	0.0044	0.0704	0.0660	1.27	River T.	Clay loam
4746	Sl. Alk.	Alk.	0.0066	0.0462	0.0396	1.43	V. F. R.	Silt loam
4725	"	Sl. Alk.	0.0088	0.0968	0.0880	1.80	C.	Sandy clay
4701	"	Alk.	0.0110	0.1034	0.0924	3.35	C.	Sandy loam
4724	Alk.	Sl. Alk.	0.0132	0.0770	0.0638	1.79	V. S. Y.	Sandy loam
4744	"	Alk.	0.0132	0.0660	0.0528	1.31	C.	Silt loam
5065	"	"	0.0143	0.0528	0.0385	1.09	C.	Clay loam
4739	"	Sl. Alk.	0.0281	0.1496	0.1215	3.49	V. F. R.	Black clay loam
4730	"	Alk.	0.0484	0.1232	0.0748	1.93	P.	Clay loam
4741	"	"	0.0506	0.2168	0.1662	6.48	Alluvial	Black clay loam
4751	"	"	0.0506	0.0814	0.0308	0.98	V.	Silt loam
4712	"	"	0.0539	0.1210	0.0671	1.96	C.	Clay loam
4749	"	Sl. Alk.	0.0682	0.1210	0.0528	1.13	C.	Silt loam
5063	"	Alk.	0.0792	0.1540	0.0748	1.34	V. O. W.	Silt loam
5281	"	"	0.0946	0.1782	0.0836	1.50	C.	Clay loam
5067	"	"	0.2530	0.3630	0.1100	3.26	Blk. Swale	Black clay
4698	Sl. Alk.	Neutral	0.5632	0.6809	0.1177	1.88	V. F. R.	Clay
4714	Alk.	Alk.	0.5720	0.6600	0.0880	1.23	V. F. R.	Clay loam
4743	"	"	1.5220	1.8830	0.3610	6.56	V. Alluv.	Black clay loam

Average difference, 0.0912 percent CO_2 = 4144 pounds $CaCO_3$ per acre, 7 inches by official method.

The total phosphorus content of practically all Ohio soils is less than that of any of the other constituents considered essential for crop production. The analyses of the soils reported here show that the average total phosphorus in the surface soil is approximately .06 percent, which, expressed as pounds per acre of soil to the depth of 6 inches, is about 1,200 pounds. The total phosphorus content has been found to be greater in the surface than in the subsoil, except in four instances, where the subsoil contained large quantities of calcium carbonate.

The smallest quantity of phosphorus found in the soils from different sections of Ohio was .025 percent, equal to 500 pounds per acre 6 inches of soil.

An invoice of the soil's phosphorus supply compared with that of potassium and nitrogen leaves no doubt of the importance of obtaining all the information possible concerning this element. There is an abundance of total potassium in all Ohio soils examined except those classed as peats. About 1.80 percent, approximately 36,000 pounds of potassium per acre, is the average amount found in the surface 6 inches.

The producing power of a soil, so far as the plant food supply is concerned, depends not alone upon the total amount present, but is influenced to a greater extent by the availability. No method has been devised which will properly measure what proportion of this great store of potassium may be in a condition capable of being assimilated by plants. Field tests have demonstrated that soils containing an abundance of potassium do have potassium liberated for the needs of crops by the right system of soil management, which includes the use of lime if needed, and the growing and returning to the soil, of leguminous crops. Nitrogen may be added to the soil by following the same practice. Aside from increasing the nitrogen content of the soil and supplying organic matter which liberates potassium, the growing of leguminous crops furnishes potassium assimilated from the lower soil strata. Leguminous plants are heavy potassium feeders and their deep root system enables them to draw upon supplies which are below the range of other farm crops.

But for the majority of soils, the phosphorus supply must be replenished by using fertilizers carrying phosphorus. The form of phosphorus to be used depends somewhat upon the character of the soil. Bone meal and basic slag phosphate will be better adapted than acid phosphate for soils with only a small amount of organic matter and containing no calcium carbonate, while on soils containing liberal quantities of calcium carbonate, acid phosphate will give

better returns for the money invested than if used on acid soils. Raw rock phosphates give practically no return on the money invested if used on soil not liberally supplied with active organic matter.*

CALCIUM CARBONATE AND PHOSPHORUS RELATION

The results obtained point out the fact that soils containing calcium carbonate have a larger amount of phosphorus than soils containing no calcium carbonate. By referring to the summarized data given in Table I, page 451, it will be observed that the average phosphorus content of surface soils containing calcium carbonate is 1,310 pounds per acre, compared with 913 pounds and 986 pounds in the non-calcareous soils from the western and eastern sections.

In cases where the phosphorus content is from .3 to .1 per cent, four of the seven surface soils showing this range in phosphorus contain calcium carbonate, and three give an alkaline reaction to litmus paper. Four out of ten soils containing phosphorus varying from .1 to .07 percent have calcium carbonate present; three of these ten soils are alkaline, and three are neutral in their reaction to litmus paper. When the phosphorus content is from .07 to .06 percent, five out of nine soils contain carbonates and two are alkaline. Out of nineteen soils containing phosphorus varying from .06 to .05 percent, four contain carbonates and only two show an alkaline reaction. In soils having .05 to .04 percent phosphorus, seven of the nineteen soils analyzed contain calcium carbonate; four give an alkaline and two a neutral reaction. Where the phosphorus decreases from .04 to .025 percent, the smallest amount found, two out of the fifteen soils contain calcium carbonate and these two show an alkaline reaction.

Hilgard in his work on soils, calls attention to the fact that, in soils having high lime percentages, relatively low percentages of phosphorus are adequate for good crop production; while the same or even higher amounts of phosphorus, in soils without sufficient lime, may be less than is necessary for crop needs. It is assumed that calcium phosphates are more available than phosphates of iron and aluminum. There are no doubt other reasons, why soils supplied with basic calcium compounds have more of their phosphorus available, than that of the function performed by calcium carbonate in maintaining part of the soil phosphorus supply as calcium phosphates, rather than in the form of iron and aluminum phosphates. The soil bacteria render phosphorus and other mineral plant nutrients available, and their activities are increased by maintaining a neutral or alkaline reaction in the soil.

*These points are being investigated at this Station.

The phosphorus taken into solution when a soil is digested with fifth normal nitric acid is mostly phosphate of calcium. For this reason, nitric acid of this strength is used to measure the more easily assimilated soil phosphates.

Investigations reported by the Wisconsin Experiment Station* show that acid soils lack available phosphorus. It is stated for Wisconsin soils, that if the fifth normal nitric acid-soluble phosphorus falls below .015 percent phosphoric acid (P_2O_5), equivalent to .0065 percent phosphorus, the soils respond to fertilizers carrying phosphorus.

The relations found to exist between the fifth normal nitric acid soluble phosphorus, calcium carbonate content and soil reaction of the soils studied, indicate that soils which contain calcium carbonate and give an alkaline reaction have more available phosphorus than non-calcareous acid soils.

The averaged results for phosphorus in the calcareous and non-calcareous soils of the several different classes are included in Table IV, page 469.

It will be noticed that soils naturally calcareous contain a much larger amount of phosphorus soluble in fifth normal nitric acid than is found in the non-calcareous soils. Sandy soils contain much more soluble phosphorus than do silts and clays. The amounts of phosphorus soluble in fifth normal nitric acid found in calcareous and non-calcareous sandy soils is much greater than for the corresponding divisions of silts and clays. The proportion of total phosphorus content of acid sandy soils, soluble in fifth normal nitric acid, is only slightly less than that found for the calcareous soils of the other two classes, silts and clays.

ORGANIC MATTER

The content of organic matter is an important factor in determining soil differences; this is especially true in regard to its effect on physical properties. Of no less importance is its relation to availability of mineral plant nutrients, due to the solvent action of carbon dioxide, liberated from the decomposition of vegetable matter incorporated with the soil. The mineral constituents are continually being subjected to the same action of air and water as gave rise to the formation of soil from rock: but the changes produced by these agencies take place at a more accelerated rate where larger amounts of active organic matter are present, because increased quantities of carbon dioxide are furnished. The necessity of maintaining a sufficient supply of organic matter by the use of manure, and incorporating with the soil leguminous and other crops,

*Whitson and Stoddart, Research Bulletin No. 2, 1909, Univ. of Wis.

is generally recognized. Some attribute little value to the vegetation returned to the soil, other than that it supplies organic matter. It must be remembered that plant remains carry considerable quantities of fertilizing materials, including nitrogen, and that these have a value comparable with that of the same plant nutrients in commercial fertilizers.

The color of soils gives some indication of the amount of organic matter present, but the influence of mineral materials present, and the nature and extent of the decomposition of incorporated organic material, are such that equal amounts will not produce the same color in different soils. A measure of the supply of carbonaceous material in the soils studied has been obtained by making the so called humus determination. The greater number of the soils examined contained less than 2 percent humus; in two of the black clay loams the amount found was 6 percent; the average for the black clay loams being 3.5 percent. Determinations of nitrogen and humus show that the nitrogen gives a measure of the humus content; in most instances the amount of humus is ten times the nitrogen found. The soil nitrogen is practically all contained in the organic matter and this supply of nitrogen, compared with the carbon of the organic matter, gives some indication of the character of the organic material present.

Soils containing old organic residues will have a less proportion of carbon to nitrogen than those in which fresh supplies of organic matter have been more recently incorporated. Drainage and supply or deficiency of calcium carbonate are important factors affecting the condition of the organic material in soils. The results for total humus and total carbon, obtained in this laboratory, show that for a large number of soils the organic matter extracted with a 4 percent ammonium hydrate solution approximates very closely the total carbon content. Considering the humus results as total carbon, and comparing the ratio of humus to nitrogen in the calcareous and non-calcareous soils, it is found that those naturally supplied with calcium carbonate have a less proportion of carbon to nitrogen than the soils which contain no calcium carbonate. As a general rule there is a greater proportion of carbon to nitrogen in the cultivated soils than in the uncultivated soils from fence rows and woodlands adjacent to the cultivated areas sampled. Averaged results for the different classes of soil examined show that the sands and sandy loams have more carbonaceous matter, in proportion to their nitrogen content, than the soils classed as silts and clays.

TABLE VII. Composition of soil from Wooster farm, sampled in 1896 and 1911. Results expressed as pounds per 2,000,000 pounds of soil.

Description	Depth inches	Phosphorus		Potassium		Nitrogen	Humus	Calcium		Magnesium	
		Total	Soluble	Total	Soluble			Total	Soluble	Total	Soluble
5-yr. rotation, sampled 1896.	0-6	742	6	34,104	162	2,114	22,200	4,740	1,072	6 596	158
5-yr. rotation, sampled 1896.	6-12	652	4	35,910	130	1,350	......	4,400	1,080	8,630	224
5.yr. rotation, sampled 1911.	0-6	664	4	33,110	144	1,778	18,800	4,720	882	7,778	186
5-yr. rotation, sampled 1911.	6-12	598	2	36,100	138	1,266	......	4,400	1,094	9,592	250
Variety field, sampled 1911...........	0-6	1,030	60	33,202	236	2,430	22,800	5,200	1,726	7,064	424
Variety field, sampled 1911...........	6-12	860	14	35,360	146	1,510	......	4,410	1,280	8,550	350

VALUE OF SOIL ANALYSIS

When the changes induced by cropping and fertilizing are sufficiently pronounced to be detected by a chemical analysis the results obtained indicate the value of such an analysis. The composition of the soil from the farm at the Wooster Station shows that measurable changes have occurred during a period of 15 years. The analyses of samples taken in 1896 from the unfertilized and unlimed soils of the 5-year rotation fertility plots are compared with the analyses of the soils secured from the same plots in 1911. A comparison of these results with the composition of soils from another part of the farm, designated as the variety field, and which is used for a four-year rotation of corn, oats, wheat and clover, serves to contrast the difference in chemical composition of a non-productive soil and the same soil brought to a high state of fertility by treatment. The soil samples taken in 1896 are representative of the condition and composition of the soil at the time the Station's fertility investigations on these soils were begun. From an inspection of the results, which are expressed as pounds per 2,000,000 pounds of soil, in Table VII, page 498, it will be observed that the phosphorus, potassium, nitrogen and humus decreased an appreciable amount in 15 years, which is in accordance with the crop history. A different condition is noticed in the case of the magnesium, for both depths of soil contained more of this element at the time of sampling in 1911, than was found in the samples taken in 1896. The amounts of total phosphorus, nitrogen and humus are greater in the soil from the variety field than in the unlimed and unfertilized soil of the 5-year rotation plots; the soluble phosphorus and potassium are also greater. The variety field plots have been limed and liberally treated with manure and fertilizers carrying phosphorus, potassium and nitrogen. The large crops of clover grown on this part of the farm once in four years are responsible for the increased quantities of nitrogen and humus stored in this soil, as compared with the impoverished soil of the unlimed and unfertilized plots of the 5-year rotation sampled in 1911. The amount of organic matter carrying nitrogen in the variety field soil is only slightly greater than the amount present in the 5-year rotation soil when sampled in 1896.

The fertility of the unfertilized and unlimed soil has been decreasing. Without the aid of lime, no clover grows on this soil to maintain a supply of organic matter.

SUMMARY

The work herein reported shows differences in calcareous and non-calcareous soils which are representative of many of the soil types found in Ohio. Special attention has been directed to the phosphorus content.

Soils, containing no calcium carbonate, from counties in the western part of the State have larger amounts of total and fifth normal nitric acid-soluble calcium and magnesium than the soils from the eastern counties overlying sandstone and shales; this illustrates the gradual loss of calcium carbonate in soils which were originally of limestone formation.

The different grades of soil examined, sands, silts and clays, do not exhibit any marked differences in chemical composition. Clays and clay loams generally contain less total silicon and slightly increased percentages of iron, aluminum and potassium.

When these soils are considered with respect to their calcium carbonate content, considerable differences in the amounts of total and fifth normal nitric acid-soluble constituents are found. Calcareous soils contain less total silica and are more liberally supplied with phosphorus and potassium than the non-calcareous soils.

Black clay loams contain larger amounts of phosphorus and nitrogen than the other soils analyzed; these soils were of limestone origin and all except two contained calcium carbonate.

In sampling the soils studied, two depths were taken, the surface 6 inches and 6 to 36 inches called subsoil. One of the marked differences between the surface soil and the lower stratum is that the surface soil contains more phosphorus than the subsoil; this was found to be the case except in a very few instances where the subsoil contained considerable quantities of calcium carbonate. The nitrogen associated with the increased amounts of organic matter is present in greater quantity in surface soils.

Aside from their phosphorus content and amount of incorporated organic matter from plant remains, the chief distinction between the surface soil and the subsoil is their difference in texture. The surface soil contains more fine particles than the subsoil. This is shown by the relative proportion of the more abundantly distributed soil constituents found in the two depths; more total silicon is present in the upper layer of soil, while the lower stratum contains increased quantities of silicon soluble in fifth normal nitric acid, and more total iron, aluminum and potassium.

The calcium and magnesium content is of interest. In soils containing no calcium carbonate, more calcium is present in the surface than in the subsoil, while the subsoil contains more magnesium.

Both calcium and magnesium are present in larger amounts in the subsoil than in the surface 6 inches of soils containing calcium carbonate; the calcium being in excess of the magnesium, while for non-calcareous soils magnesium is always greater than the calcium in the subsoil. The greater number of non-calcareous soils contain more magnesium than calcium. All the soils examined have a much larger amount of calcium than of magnesium soluble in fifth normal nitric acid.

The relation between soil acidity and calcium carbonate, which has been investigated in regard to phosphorus availability as measured by chemical methods, shows that the litmus paper test, if properly made, is a satisfactory qualitative test for the presence or absence of natural calcium carbonate in soils. Of 126 surface soils examined for calcium carbonate and reaction, only five of those containing calcium carbonate reddened blue litmus paper. All the soils which gave an alkaline reaction with red litmus contained calcium carbonate.

The loss of calcium carbonate from cultivated soil is indicated by the amount residual from an application of 12,000 pounds per acre to an acid soil. This soil was limed in 1907 and an analysis in 1912 showed a loss of 9,900 pounds during the five years.

Many of the surface soils from the western section of the State contain considerable quantities of calcium carbonate and in practically all cases the corresponding subsoil contains an increased amount. All soils from the eastern section show a decided deficiency of calcium carbonate.

The total phosphorus content of the soils studied varies from .30 percent or 6,000 pounds per acre to .025 percent or 500 pounds of phosphorus per acre six inches of soil. Fourteen of the one hundred and twenty-six surface soils examined show the presence of more than .10 percent of total phosphorus.

The averaged results of the chemical examination of a large number of calcareous and non-calcareous soils show that those containing calcium carbonate have a larger supply of total phophorus than the non-calcareous soils. The average phosphorus content of calcareous surface soils is 1,310 pounds per acre, compared with 913 pounds and 986 pounds for the non-calcareous soils from the eastern and western sections of the State.

Soils classed as black clay loams contained the largest amount of total phosphorus followed by the calcareous clays and clay loams.

Considering the fifth normal nitric acid-soluble phosphorus to be a measure of phosphorus availability, the results obtained show

that soils giving an alkaline reaction and containing natural supplies of calcium carbonate have a greater supply of available phosphorus than do acid soils.

The soils classed as sands and sandy loams have a larger proportion of their total phosphorus content soluble in fifth normal nitric acid than do the silts and clays, 30 percent of the total phosphorus in the calcareous sands and sandy loams being soluble. The amount of fifth normal nitric acid-soluble phosphorus in the non-calcareous sands and sandy loams is approximately the same as found for the calcareous silts and clays.

The fifth normal nitric acid-soluble phosphorus of the black clay loams which are calcareous is greater than that of any of the other classes of soils, with the exception of calcareous sands and sandy loams.

A deficiency of available phosphorus is indicated by the low solubility of phosphorus for the non-calcareous silts and silt loams, clays and clay loams which show an acid reaction.

ADDENDA

METHODS OF SOIL ANALYSES

Collecting sample: From 10 to 20 borings with a 1-inch soil auger are taken and thoroughly mixed. When samples are not taken below a depth of 2 feet, a more satisfactory sampling can be made with a soil sampling tube.

Preparation of sample: After the sample is thoroughly air dried it is pulverized in a porcelain pebble mill to pass a 0.5 mm. sieve. For total constituents a sub-sample of 50 grams is reground to pass fine bolting cloth (No. 15). All samples are carefully preserved in tight glass containers.

Moisture: Five grams of finely pulverized soil are weighed into an aluminum drying dish 2½ inches in diameter and 1 inch deep, provided with a tight cover. The soil is dried at a temperature of 110° C. for 5 hours, covered and allowed to cool in desiccator previous to weighing.

TOTAL CONSTITUENTS

Fusion for silicon and aluminum: Weigh .5 grams of soil into a platinum crucible containing 2.5 grams of a mixture of sodium and potassium carbonates, mixed in molecular proportion. After the soil is thoroughly mixed with the fusion mixture the crucible is covered and the contents melted at a moderate heat over a Bunsen burner; when fused the crucible is heated over blast until the soil is completely decomposed, this requires about 15 minutes. The melt is poured as quickly as possible into a dry platinum dish set in a beaker containing sufficient water to cover about one-sixth of the outside of the dish. As soon as the bead is sufficiently cool, as indicated by the sinking in of the top, it is transferred to a beaker containing 60 cc. of water in which the crucible containing the remainder of the fusion has previously been placed (the crucible can easily be cleaned in from 5 to 15 minutes and the whole sample is frequently disintegrated in this time). The crucible is washed out with a small quantity of hydrochloric acid, transferring the washings to a covered beaker containing the bulk of the fusion; when the sample is thoroughly disintegrated a small excess of hydrochloric acid is added from a burette, through the lip of the covered beaker. The beaker is placed on steam bath and after all effervescence has ceased the cover is removed and the solution evaporated to dryness; allowed to bake for one hour* when 3 cc. of hydrochloric acid and 10 cc. of water are added. The sample is well broken up with a stirring rod and again evaporated to dryness. The residue is taken up with

*Do not stir solution or break up gelatinous mass, but allow it to evaporate and bake until ready to add HCl.

dilute hydrochloric acid and heated on steam bath until all salts are dissolved; the separated silica is filtered out and washed a few times with dilute hydrochloric acid. After washing free from chlorides the silica is ignited in platinum crucible for at least 30 minutes and weighed.

Aluminum: Aluminum may be determined in the filtrate by either the potassium hydroxid or the sodium thio-sulphate method. For soils containing considerable calcium carbonate the latter method is preferable. When the aluminum content is very high, if the potassium hydroxid method is used, two precipitations are necessary, adding a small amount of phosphate solution before making the second precipitation. The double precipitation facilitates the removal of occluded potassium salts.

Potassium hydroxid method for aluminum: The filtrate from the silicon determination is concentrated to 100 cc., transferred to a 200 cc. flask containing 50 cc. of a 10 percent solution microcosmic salt or ammonium phosphate, and 20 cc. of a 50 percent potassium hydroxid solution. The contents of the flask are heated to 100° for 30 minutes with occasional shaking. After cooling to room temperature the solution is made up to 200 cc., thoroughly shaken and filtered. Of the clear filtered solution 100 cc. (equal to .25 grams of soil) are diluted to about 200 cc.; a few drops of methyl orange are added and the solution slightly acidified with nitric acid, then made slightly alkaline with ammonium hydroxid. After heating at a temperature of 65° until the precipitate settles, which requires about 30 minutes, the precipitate is filtered off and washed 15 times with a 5 percent solution of ammonium nitrate. After drying between blotting paper it is ignited over a blast for 20 minutes, cooled and weighed as $AlPO_4$.

Sodium thio-sulphate method for aluminum: The filtrate from the silicon determination is neutralized with ammonium hydroxid and slightly acidified with hydrochloric acid; 2 cc. concentrated hydrochloric acid and 10 cc. of a 10 percent solution of ammonium phosphate are added. The solution is evaporated to 300 cc.; then 10 grams of sodium thio-sulphate and 15 cc. of acetic acid (one part glacial acetic acid and two parts water) are added. After heating on hot plate for 15 minutes the precipitated aluminum phosphate and admixed sulphur are filtered off, washed with a hot 5 percent solution of ammonium nitrate, ignited and weighed as $AlPO_4$.

Iron: One gram of finely ground soil is fused as for total silicon. After evaporation and filtering off SiO_2, iron is precipitated from the filtrate with ammonium hydroxid; the precipitated iron is filtered, washed 6 times with hot water and transferred from filter

paper into precipitating beaker by means of a jet of hot water. After dissolving in hydrochloric acid, iron is determined with N-100 potassium bichromate solution following the usual procedure.

Calcium: One gram of the finely ground soil is fused as directed under the method for total silicon. The filtrate from the separated silica is treated as follows: The volume being about 150 cc. (2 cc. of a 10 percent solution of ferric chloride may be added)* a slight excess of ammonium hydroxid is added to the solution; after heating to boiling, the precipitated iron and aluminum hydroxides are filtered off on 11 cm. filter paper and washed 4 times with hot water. The precipitate is washed from the filter paper back into the beaker in which the precipitation was made. A slight excess of hydrochloric acid is added and heated until solution is complete. A second precipitation of iron and aluminum is made, the filtrate being received in beaker containing the first filtrate. The solution is evaporated to about 250 cc., made alkaline with ammonium hydroxid and allowed to cool. Sufficient bromine water (approximately 20 cc.) is added to precipitate the manganese; after heating to boiling the manganese is filtered off and washed. The volume of the filtrate being about 200 cc., calcium is precipitated as oxalate by the addition of ammonium hydroxid and a small excess of a saturated solution of ammonium oxalate to the hot solution; heat to boiling for fifteen minutes, allow to stand on steam bath for two hours or if more convenient over night. The precipitated calcium oxalate is filtered on asbestos mat in filter tube, using suction, and washed with hot 2 percent ammonium hydroxid solution. The precipitate and asbestos mat are transferred to precipitating beaker; 100 cc. of distilled water and 25 cc. of concentrated sulphuric acid added. Mixture of acid and water will generate sufficient heat for titration. Calcium is determined volumetrically with N-20 potassium permanganate solution.

Magnesium: The filtrate from the precipitation of calcium oxalate is evaporated in a 400 cc. beaker to about 100 cc.; after cooling, 20 cc. concentrated nitric acid are added, the beaker covered and evaporated to dryness on hot plate to remove ammonium salts; 10 cc. of hydrochloric acid are added and the solution evaporated nearly to dryness. The residue is dissolved in hot water and a small amount of hydrochloric acid; if necessary the solution is filtered, and the filter paper washed with about 100 cc. of hot water. The volume of the solution being about 100 cc., the magnesium is precipitated as magnesium ammonium phosphate by the addition of 3 cc. of a 10 percent solution of ammonium phosphate and sufficient ammonium

*To facilitate filtering and washing.

hydroxid to make the solution slightly alkaline; stir vigorously; allow to stand fifteen minutes and add 15 cc. of ammonium hydroxid and allow precipitation to proceed over night. Precipitate is filtered off on a 9 cm. filter paper and washed with a 2 percent ammonium hydroxid solution; placed in porcelain crucible, dried and ignited in electric muffle furnace.

Manganese: One gram of soil is fused as previously directed for total silicon. When the sample is thoroughly disintegrated add an excess of nitric acid; evaporate to dryness on steam bath; take up residue with 50 cc. 1-1 nitric acid; heat to effect solution and filter. Evaporate solution to a volume of 50 cc. and add .5 gram of sodium bismuthate, agitating solution for 15 minutes; then add 50 cc. of 3 percent nitric acid; filter through asbestos mat into a 300 cc. Erlenmeyer flask, using suction; wash with 50 to 100 cc. of 3 percent nitric acid. Run into filtered solution a measured excess of ferrous ammonium sulphate solution and titrate to a faint pink color with standard permanganate. For further details of the method see Blair's Chemical Analysis of Iron, 7th edition, pp. 121-122; or The Journal of Am. Chem. Soc., Vol. XXV, p. 793. The first treatment with sodium bismuthate is omitted because all oxidizable substances, organic matter and hydrocarbons have been destroyed by fusion.

Phosphorus: The magnesium nitrate method is used for the determination of total phosphorus.* Weigh into a 50 cc. porcelain dish 5 grams of soil, moisten with 5 to 7 cc. of magnesium nitrate solution (Bureau of Chem., Bulletin 107, Rev., p. 2, Sec. g.), bring to dryness on steam bath and burn off organic matter at low redness; when cool break up with a heavy glass rod and moisten slightly with water; add 5 cc. of concentrated hydrochloric acid and 3 cc. of concentrated nitric acid; digest for 2 hours on steam bath, keeping dish covered and stir 2 or 3 times during digestion. Transfer into 250 cc. flask having excess of hydrochloric acid present; make up to a volume of 250 cc. Mix well and throw on a dry folded filter, pouring back on the filter until the solution runs through clear. Make the determination on aliquots corresponding to 2 or 4 grams of soil, depending upon the amount of phosphorus present; bring to dryness on steam bath and take up with 4 cc. concentrated nitric acid and water; evaporate to dryness the second time, taking up with 2 cc. nitric acid and hot water. Filtrate and washing should not exceed 50 cc. Add gradually while stirring 5 to 15 cc. of molybdate solution (Bureau of Chemistry, Bull. 107, Rev., p. 2); allow to stand a minute or two and add 5 grams of dry ammonium nitrate, stirring thoroughly. Heat the solution at a temperature of 40 to 50° for one hour and allow to

*Proceedings of the Association of Official Agricultural Chemists, Bureau of Chemistry, Circular 43

stand over night at room temperature. Filter on asbestos pad placed in filtering tube; wash well with cold water or a .25 percent solution of potassium nitrate. Transfer filtering pad and precipitate to precipitating beaker using as little wash water as possible. Determine phosphorus volumetrically, using standard potassium hydroxid and nitric acid.

Potassium: The fusion for total potassium is made according to the Lawrence Smith method for total alkalies. After the alkalies are dissolved out of the fusion several modifications of the usual procedure for the determination of potassium are used. Grind very thoroughly in agate mortar 0.5 gram of soil with 0.5 gram of ammonium chloride; when finely ground add 4 grams of calcium carbonate and grind until well mixed. Place a little calcium carbonate in the bottom of a clean, dry, Smith crucible, then charge the crucible with the contents of mortar, and finally rinse mortar with about 0.5 gram of calcium carbonate, which add to crucible together with the brushings from paper on which mortar has stood while grinding. Tap well to settle; place in asbestos cylinder and heat at low temperature until ammonium fumes no longer escape. Move crucible frequently so as to heat all parts of mixture alike. Avoid heating hot enough to cause escape of ammonium chloride. Next turn up burner and heat for 45 minutes at the highest temperature to be secured with a good Bunsen; this will be at a bright red but a little short of whiteness. A piece of wire gauze over the top of the cylinder will prevent the burner from being easily extinguished by drafts. Turn the crucible often. Let cool, rinse cover of crucible into a 4-inch porcelain dish; loosen fusion from crucible with the aid of glass rod if necessary and transfer to dish; fill crucible with hot water, let stand a few minutes, rinse into dish; cover with large watch glass and let stand until fusion slakes thoroughly; this slaking usually takes place readily enough, but with some samples not. This, however, makes little difference. The fusion should stand thus over night, at least, although heating on the steam bath will hasten disintegration. When ready to filter, grease lip of dish, stir up contents with rod, and decant onto 11 cm. filter; receive filtrate in 400 cc. Jena beaker. Grind residue in dish with pestle, add some boiling water, stir up and decant; repeat a couple of times. Grind residue again and transfer all to filter. Rinse dish twice with hot water onto filter. Wash eight times on filter with boiling water. This will usually fill the beaker and is amply sufficient. It is useless to attempt washing free from chlorine.

To the filtrate in beaker add 10 cc. concentrated hydrochloric acid, chemically pure, and evaporate, first, on hot plate, almost to dryness, then on steam bath, to dryness, or as nearly as possible.

Filter with suction into 150 cc. beaker covered with perforated watch glass; filtrate will almost fill beaker. This filtration removes a slimy material which appears to be derived from the action of the caustic lime upon the filter during the first filtration, and a considerable amount of silica which would render the final filtration extremely slow. Add 1 cc. concentrated hydrochloric acid and 5 cc. platinic chlorid solution of such strength that 1 cc. equals 1 percent K_2O on 0.5 gram sample; evaporate on steam bath until solid; let cool; add 15 to 20 cc. acidulated alcohol and let stand until calcium chloride is dissolved. (Acidulated alcohol is made as follows: To 1500 cc. of 95 percent alcohol add 1139.9 cc. hydrochioric acid, sp. gr. 1.20, and pass enough hydrochloric acid gas into solution to make it 2.25—normal hydrochloric acid.) Filter in special potassium filter tube,[1] transfer all precipitate from beaker to filter, using 80 percent alcohol. Wash several times with Gladding wash, finally about 6 times with 80 percent alcohol. Dry filter tube, wash with hot water into weighed platinum dish, evaporate on steam bath to dryness, place dish covered with watch glass in drying oven and heat for 1 hour at 120° C.; weigh as K_2PtCl_6.

Carbonates: The method used is a modification of the method devised by Marr[2], using the apparatus devised by Gaither[3]. The procedure is as follows: From 2 to 20 grams of soil (depending upon the carbonate content) and 80 cc. of distilled water free from carbon dioxide are put into 250 cc. Jena reagent bottle; after thoroughly mixing the bottle is connected to apparatus and vacuum pump started. When a vacuum of 65 to 70 cm. is obtained 20 cc. of hydrochloric acid solution (2 cc. hydrochloric acid, 1.19 sp. gr. to 18 cc. of water) are run from separatory funnel into the bottle in which carbon dioxid in the soil is liberated. Boil for 30 minutes, keeping bottom of bottle about three-fourths inch above gauze, protecting it from the free flame; if liquid is thrown up into condenser, the flame should be lowered. The evolved carbon dioxid is absorbed in sodium hydroxid solution using NaOH made from metallic sodium, (25 cc. of 4 percent solution of sodium hydroxid and sufficient carbon dioxid free water to cover solid beads in absorption tower). After boiling 30 minutes, vacuum is relieved and liquid drawn out of absorption tower into 250 cc. beaker or flask. The tower is washed out with 250 cc. carbon dioxid free water. Add 1 cc. phenolphthalein and run normal hydrochloric acid into solution until red color begins to fade; finish titration with N-20 hydrochloric acid. When end point with phenolphthalein is reached add 2 drops of methyl orange

[1]Jour. Ind. Eng. Chem., 4. p. 436.
[2]Jour. Agr. Sci., Vol. 3, Pt. 2, pp. 155-160.
[3]Jour. Ind. & Eng. Chem., Vol. 4, p. 611

solution, (1 gram to 1000 cc.) and titrate with N-20 hydrochloric acid. Continue the addition of acid until the lemon color of the alkaline methyl orange just darkens to a slight orange color. No account is taken of the cc.'s of acid used in titrating to end point with phenolphthalein. From the cc.'s of N-20 hydrochloric acid used subtract blank which will be approximately 4 cc. 1 cc. N-20 hydrochloric acid—0.0022 gram CO_2; equivalent to 0.0028 gram CaO or 0.005 gram $CaCO_3$.

Organic carbon: The combustion of the organic matter in soil is effected in a Parr calorimeter bomb by means of sodium peroxid and metallic magnesium as described by Pettit[1]. The carbon dioxid from the resulting sodium carbonate is determined volumetrically by the double titration method described under carbonates. The apparatus for carbonates in soils is used for the decomposition of the sodium carbonate and absorption of carbon dioxid liberated.

Nitrogen: Nitrogen in soils is determined by the Kjeldahl method completing the oxidation with potassium permanganate. Either 10 or 20 grams of soil are used, depending upon the organic content of the soil. Instead of transferring digested soil and solution from the 500 cc. glass digestion flask to copper distilling flask as is the usual practice, the digestion and distillation are made in the same flask. This is made possible by adding 2 grams of coarse aluminum to the flask when the distillation is started. The aluminum prevents bumping and the distillation proceeds quietly.

Organic matter soluble in 4 percent ammonium hydroxid solution: This portion of the soil organic matter which is ordinarily designated as "humus" is determined as follows: Five grams of soil with 250 cc. of 1 percent hydrochloric acid are placed in a liter bottle and agitated in shaking machine for 2 hours. The solution is filtered off through alundum extraction tube (33 mm. diameter at open end and 95 mm. long) which is fitted into glass cylinder connected with filtering flask. The acid extracted soil is washed with cold water to remove material dissolved by the acid treatment. The filtering tube is reversed and the soil washed out with 500 cc. of 4 percent ammonium hydroxid into original bottle, using suction. The bottle is placed in shaking machine and shaken for 5 hours. After standing over night to allow the coarse material to settle out, 300 cc. of solution are decanted into a 500 cc. stoppered cylinder. Sufficient dry ammonium carbonate is added to coagulate the clay particles. After standing a sufficient time the ammonium hydroxid solution is filtered through alundum extraction tubes. An aliquot of the solution free from clay is evaporated in tared platinum

[1]Jour. Am. Chem. Soc., Vol. 26, p. 295.

dish and the determination completed as usual. This method has been used in this laboratory for the past seven years and gives satisfactory results.

METHODS FOR N-5 NITRIC ACID SOLUBLE CONSTITUENTS

Preliminary digestion: Weigh 10 grams of soil into an Erlenmeyer flask; add 100 cc. N-5 nitric acid and allow to stand 5 hours at room temperature, shaking at intervals of 30 minutes; filter through a folded filter into a dry flask, rejecting the first 25 cc. of filtrate. Pipette off 20 cc. (equal to 2 grams of soil) and titrate with N-5 potassium hydroxid solution, using phenolphthalein as indicator. Subtract the cc.'s of potassium hydroxid used from the 20 cc.'s of N-5 nitric acid required to neutralize the bacidity of the soil; this added to original 20 cc. will give the amount of acid necessary to have very nearly N-5 nitric acid when digestion is complete.

Final digestion: Weigh 200 grams of soil into a 2500 cc. Winchester bottle and add 2200 cc. of nitric acid of such a strength that will give N-5 nitric acid at end of digestion. Shake until well mixed and digest at room temperature for 5 hours, shaking at intervals of 30 minutes. When digestion is complete, shake contents of bottle and pour into 32 cm. folded filter reenforced with 15 cm. round filter receiving the first 150 cc. in beaker and returning same to the filter paper. When the filtrate runs through clear it is received in dry Winchester bottles.

Silicon: Of the clear filtered solution 200 cc. are evaporated to dryness; taken up with 10 cc. concentrated hydrochloric acid and again evaporated to dryness, keeping beaker covered to prevent spattering of solution caused by the action of hydrochloric acid on nitrates. When thoroughly dry the residue is taken up with 5 cc. of hydrochloric acid and hot water; heated a few minutes and filtered through 9 cm. filters, washed 4 times with 1-6 hydrochloric acid and then with hot water until free from chlorides, then ignited and weighed.

Calcium: To the filtrate from silicon determination 2 cc. of 10 percent ferric chlorid solution and a slight excess of ammonium hydroxid are added. The precipitated iron and aluminum hydroxides are filtered and washed a few times with hot water. Transfer precipitate from filter to precipitating beakers; dissolve in hydrochloric acid and reprecipitate. The second filtration is made on the same filter and the filtrate received in the beaker containing the first filtrate. After evaporating to 100 cc. the solution is cooled then made alkaline with ammonium hydroxid, adding 1 cc. excess; 25 cc. of bromine water are added, allowed to stand without

heating for a few minutes and covered with watch glasses and heated to boiling until the precipitated manganese settles out. A slight excess of acetic acid is added and the precipitate filtered and washed. Calcium is determined in the filtrate as outlined under the determination of total calcium.

Magnesium: Evaporate filtrate from calcium oxalate precipitate to about 100 cc.; add 30 cc. concentrated nitric acid; cover beaker with watch glass and evaporate to dryness on hot plate to expell all ammonium salts. Take up with 10 cc. hydrochloric acid and evaporate to dryness on steam bath; add 3 cc. hydrochloric acid and hot water; make alkaline with ammonium hydroxid and filter off any insoluble matter. Filtrate is slightly acidified with hydrochloric acid and magnesium is determined as under total magnesium.

Iron: Pipette 100 cc. of nitric acid solution into a beaker; add slight excess of ammonium hydroxid and heat nearly to boiling for 10 minutes; filter and wash 5 times with hot water. Wash precipitate from filter to precipitating beakers with a jet of water; dissolve with hydrochloric acid and determine iron with N-200 standard dichromate solution in the usual manner.

Aluminum: Aluminum is determined in 100 cc. of nitric acid solution, using the methods given under determination of total constituents.

Manganese: Measure off 100 cc. of soil solution into 400 cc. Erlenmeyer flask; add 15 cc. concentrated nitric acid and boil until volume of solution is approximately 50 cc.; allow to cool and add .5 gram sodium bismuthate and boil until dissolved. A few drops of 10 percent solution of sodium thio-sulphate are added until the color is destroyed. Boil off nitrous fumes; cool to 20°; add .5 gram of sodium bismuthate and finish determination as outlined for total manganese.

Phosphorus: 400 cc. of nitric acid solution (equal to 40 grams of soil) are evaporated to dryness and baked on steam bath for one-half hour. The residue is taken up with 5 cc. concentrated nitric acid and hot water; digest on steam bath until solution is complete. Filter off insoluble matter and wash; neutralize filtrate, which should have a volume of 75 cc., with ammonium hydroxid, adding a slight excess; make acid with nitric acid, adding ½ cc. excess. Add sufficient molybdate solution to precipitate the phosphorus (from 3 to 10 cc.) stirring vigorously; allow to stand for 5 minutes; add 5 grams solid ammonium nitrate and continue determination as under total phosphorus.

Potassium: Evaporate 200 cc. of nitric acid soil solution to about 50 cc. on hot plate; add 10 cc. hydrochloric acid and evaporate to dryness on steam bath, keeping beaker covered to prevent spattering. Add 5 cc. of hydrochloric acid and evaporate to dryness a second time; take up with 1 cc. of hydrochloric acid and 25 cc. of hot water; filter off separated silica on 9 cm. filter and wash thoroughly with hot water; the filtrate should have a volume of about 50 cc. Add a sufficient amount of platinic chloride solution and continue the procedure as outlined for total potassium.

EXPERIMENTS WITH POULTRY

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JUNE, 1913.

BULLETIN 262

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EXPERIMENTS WITH POULTRY

TABLE OF CONTENTS

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 262 JUNE, 1913.

EXPERIMENTS WITH POULTRY

R. M. SHERWOOD W. J. BUSS

INTRODUCTION

The data presented in the following pages constitute the first report of experimental work in poultry husbandry done at this Station. While the work is too new to afford final data along many different lines, or even along any line, yet the results that have been secured thus far are of interest and value to poultrymen. Poultry work was begun in a small way in November, 1909, by B. E. Carmichael; in December, 1910, R. M. Sherwood took charge of the poultry work and remained in charge until September 30, 1912. Since early in 1913, W. J. Buss has had charge of this work.

Trap nest records of hens are being kept; experiments with different kinds and proportions of feeds for growing chicks and for laying hens are under way; incubation tests have been begun; and further experiments in feeding for meat are in progress or in prospect. Much of this work will need to be carried on for a number of years before results may be secured that will justify the drawing of final conclusions; in some of the work, results may be secured in a relatively short time. Most of the poultry is kept at the main Station farm near Wooster; a smaller flock is kept at the Southeastern Test Farm, Carpenter, Ohio.

COST OF EGG PRODUCTION

I

The object of this work was to secure data relative to the cost of egg production and to the variation in rate and economy of production that may be expected when different lots of fowls are treated alike. The results to be compared included feed consumed, eggs laid, gain or loss in weight, mortality, and cost of production based on these factors. This experiment, conducted at the Southeastern Test Farm, began December 5, 1910, and ended December 4, 1911.

Description of pullets: The pullets used in this test were Single Comb White Leghorns. They were secured from two sources—75 April hatched pullets were purchased from one flock, and 149 April and May hatched, from another flock. The lots of pullets for the test were made up by placing as nearly as possible the same number from each source in each lot.

Housing and yarding: The pullets were housed in a 20 ft. x 60 ft. half monitor roofed laying house, similar in type to the 24 ft. x 100 ft. house illustrated on page 538. This house contains a feed room 8 ft. x 20 ft. in the west end, and four 13 ft. x 20 ft. pens. The light and ventilation were alike in all pens. During warm weather the pullets had access to a yard 13 ft. x 60 ft. in size. This yard furnished no green feed.

Ration and manner of feeding: All lots were fed the same ration. Until January 19 the grain mixture was composed of 4 parts, by weight, cracked corn and 3 parts wheat. The mash mixture up to this time was made up of bran, 1 part; linseed oilmeal, 1 part; beef scrap, (50 percent protein) 1 part. After the above date the grain mixture was composed of cracked corn, 3 parts; wheat, 1 part, and the mash mixture was composed of ground corn, 4 parts; bran, 2 parts; beef scrap, 2 parts; linseed oilmeal, 1 part. The grain mixture was fed twice daily in the litter. The mash mixture, fed dry, was kept in hoppers to which the pullets had access at all times. During the winter months a small amount of clover chaff, and during the summer a limited amount of green feed were given. Before February 12, grit and bone were fed in troughs. After that time, oyster shells were substituted for bone, and the shells and grit were supplied in small hoppers. The pullets were given access to water at all times.

Prices of feeds: In all tests reported in this bulletin, the following prices per hundredweight for feeds are used:

Corn	$1.00	Bran	$1.30	Green feed	$ .25
Wheat	1.50	Middlings	1.30	Grit	.75
Oats	1.25	Oilmeal	1.80	Oyster shells	.75
Ground corn	1.09	Beef scrap	2.75	Bone	2.50
Cracked corn	1.09	Clover chaff	.50	Charcoal	2.25

Feed consumed: Table I shows the amount and cost of the various materials consumed by each lot, and the average amount and cost per pullet.

TABLE I. Amount and cost of feed consumed per lot for the year.

Lot No.	Av. number in pen	Grain	Mash	Grain and mash	Green feed	Clover chaff	Grit	Bone	Oyster shells	Cost of feed
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
1	53 4	2520.7	1108.	3628.7	263.5	276.	15 0	32.5	84.0	$51.52
2	54.4	2555 4	1254.	3809.4	260 5	266.	15.5	12.5	100 5	52.79
3	55 5	2593.8	1205.	3798.8	260 5	279.	15.5	15.5	93.5	52.52
4	50.9	2439.6	1162.	3601.6	260.5	274.	15.0	21.0	83.0	50.15
Average amount and cost of feed consumed per pullet.										
1	....	47.204	20.749	67 953	4.934	5.169	.281	.609	1.573	96.5c
2	...	46 974	23.051	70.025	4.789	4.890	.285	.230	1.847	97 0
3	....	46.735	21.712	68.447	4.694	5.027	.279	.279	1.685	94.6
4.	....	47.929	22.829	70.758	5.118	5.383	.295	.413	1.631	98.5

Weights of pullets: The weights recorded in Table II, except for Lot 4 are for the pullets that finished the entire year. In Lot 4 the initial weight includes the weights of two pullets killed in a trap nest, while the final weight includes their weight at death. These birds are included because the loss is one that would not have occurred under ordinary conditions. The other losses were charged to the lots at the rate of 12 cents per pound. The gain in weight was credited to the lots at the same rate per pound.

TABLE II. Initial and final weight and gain for the year.

Lot No.	Initial weight Dec. 1, 1910	Average initial weight per pullet	Final weight Dec. 2, 1911	Average final weight per pullet	Total gain	Average gain per pullet	Percentage gain in weight
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Percent
1	158.7	3.174	172.1	3.442	13.4	.268	8.44
2	166.9	3.210	176.1	3.387	9.2	.177	5.51
3	172 1	3.129	192.8	3.505	20.7	.376	12.03
4	163.6	3.272	175.0	3.500	11.4	.228	6.97

Egg production: The average egg production per pullet, as shown in Table III, did not vary greatly for the different lots. The variation in egg production of Lots 1, 3, and 4 is only 1.8 eggs per pullet for the year, while the pullets in Lot 2 laid 8.4 eggs, or 7.2 percent, more per pullet than did those in Lot 1.

TABLE III. Egg production.

Lot	Average number in lot	Total eggs produced	Average eggs per pullet	Percentage egg production
1	53.4	6253	117.1	32.08
2	54.4	6829	125.5	34.39
3	55.5	6599	118.9	32.58
4	50.9	6050	118 9	32.56

Mortality: The number of pullets that died from each lot during the year was as follows: Lot 1, 6; Lot 2, 4; Lot 3, 1; Lot 4, 6. The date of death of each of these pullets is shown in Table IV.

TABLE IV. Date of death of pullets in each lot.

Lot 1	Lot 2	Lot 3	Lot 4
April 1 May 9 May 21 June 16 September 11 November 11	May 6 May 19 July 10 November 24	June 17	January 29 January 31 March 3 April 5 May 12 August 29

No explanation can be given for the variation in losses in the different lots. This variation, however, suggests the need for at least duplicating an experiment before much importance is attached to slight differences in the results secured. If the pullets in the various lots had been fed different rations, there might be a tendency to favor the ration given to Lot 3.

Of the 17 birds which died in the four lots, only 2 are of the 75 purchased from one flock, while 15 are from the 149 purchased from a different flock. In addition to this loss, two birds in Lot 4 were killed in a defective trap nest. Since these deaths were the result of experimental equipment, they are not charged against the lot.

Summary: In Table V is presented a summary of the results secured in this test. The variation in the cost of eggs per dozen from the different lots is almost 1 cent or approximately 10 percent. The cost of eggs per dozen takes into account the cost of feed, on basis of prices given on page 516, the mortality, and the gain in weight of fowls which were living at the end of the year. The feed consumed, the mortality, the gain in weight and the egg production are of more importance than is the cost as given in this table, on account of the fact that varying prices for feeds and poultry would make a considerable change in the cost of the eggs as shown.

TABLE V. Summary.

Lot No.	Average number in lot	Total grain and mash consumed	Average grain and mash consumed per pullet	Total cost[1] of feed	Average cost of feed per pullet per year	Value (at 12 cents per lb.) of gain in live weight	Value (at 12 cents per lb.) of pullets that died	Net cost[2] of eggs produced	Total eggs produced	Cost[2] per dozen eggs produced
		Lbs.	Lbs.							Cents
1	53.4	3628.7	67.953	$51.52	96.5c	$1.608	$2.328	$52.240	6253	10.08
2	54.4	3809.4	70.025	52.79	97.0	1.104	1.500	53.186	6829	9.35
3	55.5	3798.8	68.447	52.52	94.6	2.484	0.372	50.408	6599	9.17
4	50.9	3602.6	70.758	50.15	98.5	1.368	2.076	50.858	6050	10.09

[1]See page 516 for prices of feeds.
[2]Based on cost of feed, gain in weight and mortality.

The keeping of poultry for egg production is very often unprofitable. This may be due to a poor market for the product, as well as to a high cost of production. Profits may sometimes be realized where loss previously resulted, simply by more careful handling of the product and the location of a better market. On the ordinary market, the careful poultryman must sell his eggs at a price based on the price the purchaser can afford to pay for the inferior product of careless producers, from which some losses are sustained.

There are limited markets, such as high class hotels, restaurants, hospitals, city retail stores and private families, for select grades of eggs at somewhat higher prices than are paid on the common market. These markets are sometimes difficult to secure. The producer must first prove the quality of his product before a satisfactory price can be obtained. It should be remembered by both consumer and producer that when the consumer does pay a higher price for select eggs than for common grades, the increase in price to the consumer is not all clear profit to the producer, for much extra labor and expense are involved in the production and marketing of the improved product. The producer should, on account of this extra cost, secure a higher price than is ordinarily paid for common grades; while the consumer, on account of the better quality of the carefully handled product, can well afford to pay a fair premium above ordinary prices.

II

The data on the cost of egg production presented in the following pages were secured from November 25, 1911, to November 16, 1912, at the central Station at Wooster. When the building in which they were housed was completed, the pullets were placed in the different pens without regard to weight, age or breeding (except, of course, that breeds were kept separated), so that the different lots were not uniform. While these data would be of much more value if the birds in the various lots had been uniform, it is thought that these figures may be of some interest, in connection with the foregoing test, in showing the cost of egg production under conditions similar to the ones which existed when these data were secured.

The pullets in Lots 1, 2, 3 and 4 were Single Comb White Leghorns; those in Lot 5 were Barred Plymouth Rocks. They were all hatched during the spring of 1911. They were reared under practically similar conditions as regards feed and housing during the summer and fall. The average weight of the pullets, when the records for the different lots were begun, is shown in Table VII. The average age of the pullets in each lot December 1, 1911, is given in Table VIII.

The records for Lots 1 and 2 began November 25; for Lot 3, November 28; for Lot 4, December 4; and for Lot 5, November 28, 1911. The records closed November 16, 1912, for all lots. At this time the fowls were divided into lots for experimental work. Since egg production was very light when the records closed, there would have been very little increase in the egg production had the records been continued until they covered a full year, but the feed consumed would have been increased to some extent.

Forty-three of the pullets in Lot 1 began laying during the latter part of September and laid 849 eggs before the records reported here were started. Some of the pullets in Lots 2 and 5 began laying at the time the records were started, but none of those in Lots 3 and 4 began to lay until two to three weeks after the feed records were begun.

During the spring of 1912, 15, 24, 21, 60 and 109 pullets were taken from Lots 1 to 5, respectively, and placed in breeding pens. Those from Lots 1 to 4, inclusive, were in the breeding pens 39 days and those from Lot 5, 40 days. Records of feed consumed by the pullets from each lot are not available, because there were some pullets from each lot in several of the breeding pens. On this account the feed consumed and eggs produced while these fowls were in breeding pens are not included in the data presented in Tables VI, VII and VIII. The average number of pullets in each lot is secured by adding the number of days each pullet was in the lot and dividing by the number of days over which the records for the lot extend. When the pullets were taken from the breeding pens and placed in the laying house again, a number of the Barred Rocks were changed from the pen in which they had been prior to the time they were placed in breeding pens, to the other pen. On this account the records for the two pens of Barred Rocks are combined and presented as one lot. Lots 1, 2, 3 and 4 each occupied a pen 15x24 ft. (without outside yards) in the laying house at this Station. (See pages 537-41 for description of this house.) Lot 5 was equally divided in two pens.

All lots were fed alike. The grain mixture consisted of shelled corn, 4 parts, by weight; wheat, 2 parts; oats, 1 part. The mash mixture was made up of ground corn, 2 parts; bran, 3 parts; beef scrap (50 percent protein), 1 part; middlings, 1 part. From October 20 to November 16, 1912, 1 part of old process linseed oilmeal was added to the mash mixture. The grain was fed twice daily in the litter. The mash was fed dry in hoppers which were always open, and on this account a definite proportion of grain and mash was not maintained. It ranged from 42.7 percent as much mash as grain, consumed by Lot 3, to 53.6 percent as much, consumed by Lot 1. The

percentage for each lot is shown in Table VI. Green feed, consisting of timothy and clover from May 16 to November 4, and of cabbage from this time on, was used. Prior to May 16, no green feed was given. The birds had access to grit, oyster shells and charcoal during the entire time. A small amount of ground bone was placed in the grit hoppers April 4, but its use was discontinued when this had been consumed.

The total amount of feed and other materials consumed is shown in the first part of Table VI. The amount consumed per pullet is shown in the latter part of this table.

TABLE VI. Feed consumed per lot.

Lot No.	Av. number in lot	Grain	Mash	Grain and mash	Percentage of mash to grain	Oyster shells	Grit	Charcoal	Ground bone	Green feed
		Lbs.	Lbs.	Lbs.	Percent	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	82.5	3575.0	1914.80	5489.80	53.6	169.5	17.00	5.20	2.5	298.3
2	76.5	3402.5	1747.15	5149.65	51.4	181.0	36.40	9.10	2.5	298.3
3	75.8	3337.4	1425.35	4762.75	42.7	155.8	9.05	6.10	2.5	297.9
4	78.4	3346.1	1462.60	4808.70	43.7	121.8	58 40	4.05	2.5	298.3
5	151.4	8117.5	4091.60	12209.10	50.4	283.6	35.20	7.50	5.0	596.6
Average feed consumed per pullet.										
1	....	43.33	23.21	66.54	....	2.05	.206	.063	.030	3.616
2	....	44.48	22.84	67.32	....	2.37	.476	.119	.033	3 899
3	....	44.03	18.80	62 83	....	2.06	.119	.080	.033	3.930
4	....	42 68	18.66	61.34	....	1.55	.745	.052	.032	3 805
5	....	53.62	27.02	80 64	....	1.87	.232	.050	.033	3.940

The average weight per pullet at the time the records for the different lots were begun and again November 14, 1912, is given in Table VII. On account of the fact that a few pullets were sold from some of the pens and a number added during the spring of 1912, of which the weights were not recorded, the total loss for the lots is approximated by multiplying the loss in average weight per pullet by the average number in the lot. The charge for loss in weight is secured by combining this loss with the weight of pullets that died during the year, as shown in the following table.

TABLE VII. Weight, mortality and loss (—) or gain in weight.

Lot	Average initial weight per pullet	Average final weight per pullet	Average loss or gain in weight per pullet	Loss or gain in weight of lot, based on average loss or gain per pullet	Number of pullets that died	Weight of pullets that died	Total loss or gain in weight	Value of loss or gain in weight at 12c per pound
	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	
1	3.078	2.956	—.122	—10.1	2	5.9	—16.0	—$1.92
2	2.982	3.120	.138	10.6	8	21.3	—10.7	—1.28
3	2.444	3.073	.629	47.7	11	29.8	17 9	2.15
4	2.401	3 175	.774	60.7	4	9.2	51 5	6.18
5	3.858	5.291	1.433	217.0	24	126.95	90.05	10.81

A summary of the results secured in this work is given in Table VIII. The reader will find the figures showing the feed consumed per pullet, as given in the latter part of Table VI, and the eggs produced, as shown in Table VIII, of more value than the figures in this table which show the cost of production. This is due to the fact that fluctuations in the price of feeds and poultry in the same locality from time to time, and in different localities at the same time, would materially change the cost as shown in Table VIII. The figures given in this table are based upon prices for feeds as shown on page 516.

TABLE VIII. Summary.

Lot	Average number of pullets in lot	Average age Dec. 1, 1911	Length of time covered by records	Eggs produced	Cost of feed	Value of loss(—)or gain in weight	Cost of eggs[1]	Av. eggs per pullet[2]	Av. cost of feed per pullet	Av. cost of eggs per dozen[1]
		Days	Days							Cents.
1	82.5	243	358	11,678	$72.20	—$1.92	$74.12	141.6	$ .875	7.62
2	76.5	209	358	10,685	68.06	— 1.28	69.34	139.7	.890	7.79
3	75.8	185	355	8,562	62.17	2.15	60.02	113.0	.820	8.41
4	78.4	168	349	8,214	62.89	6.18	56.71	104.8	.802	8.28
5	151.4	191	355	16,540	159.21	10.81	148.40	109.2	1.052	10.77

[1]Based on cost of feed consumed at prices given on page 516, and loss or gain in weight at 12c per pound.

[2]If the eggs laid by the pullets when they were in breeding pens, as mentioned on page 520, are included, the average egg production per pullet is 141.9, 141.8, 115.1, 112.2 and 114.4, for Lots 1 to 5, respectively.

CAPON FEEDING

The object of this experiment was to compare the efficiency of a ration made up of corn, ground corn and beef scrap with that of a ration made up of corn, wheat, oats, ground corn, bran and beef scrap. This included a study of the amounts of the various feeds selected by the fowls when they had free access to each of the different feeds. Four lots of capons were used in this experiment. Lots 1 and 3 received the ration made up of the greater variety of feeds while Lots 2 and 4 received the ration composed of corn, ground corn and beef scrap.

Description of capons: The capons used to make up Lots 1 and 2 were strong, vigorous birds, hatched June 6, 1911 and caponized October 6, 1911. Those used in Lots 3 and 4 were hatched between May 23 and June 22, 1911, and caponized October 25. There was more variation in size of birds and less constitutional vigor in Lots 3 and 4 than in Lots 1 and 2. The birds were Barred Plymouth Rocks.

Housing: Each lot occupied half of a 10x12 ft. shed-roof house similar to the one shown on page 542 of this bulletin. During the early part of the experiment the capons were allowed access, during the day, to yards containing about one-fifth of an acre. These yards, however, furnished very little, if any, green feed. After January 11, the weather was so severe that the birds were confined to the houses.

Manner of feeding and watering: In order to allow the birds to eat of the various feeds as they desired, the different feeds were kept in separate divisions of a feeder. The birds had access to grit, charcoal and oyster shells at all times, and to water during the day time.

Manner of weighing birds and feed: The birds which were to make up Lots 1 and 2 were weighed on December 9 and divided into two lots of as nearly equal weight as possible. They were also started on the experimental rations on the above date. The average of three weights taken December 11, 12 and 13 was used as the initial weight of the experiment. The birds used in Lots 3 and 4 were weighed and divided into two lots on December 12, when they were started on the experimental rations. The initial weights are the average of three weights taken on December 25, 26 and 27. The final weights of Lots 1 and 2 were secured on February 6, 7 and 8, and of Lots 3 and 4 on February 5, 6 and 7. The birds were also weighed once each week to note the progress they were making. They were weighed individually each time. They were weighed in the morning before they were given access to feed and water, which had been withheld since the night previous. The feed remaining in the hoppers when the weekly weights of the birds were taken, was weighed, thus making it possible to determine the weekly consumption of feed. Grit, charcoal and oyster shells were not calculated on a weekly basis, but the total amount consumed during the entire experiment was calculated.

Mortality: During the experiment one bird in Lot 4 and two in Lot 3 died. As no diseased condition of the bodies was revealed by a post mortem examination, the cause of these deaths is not known.

TABLE IX. Feed consumed.

Lot	No. in lot	Length of test	Corn	Wheat	Oats	Ground corn	Bran	Beef scrap	Total[1]	Grit	Oyster shells	Charcoal
		Days	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	13	57	147.8	79.15	3.95	29.05	2.20	9.20	271.35	.80	2.3	1.40
2	13	57	181.2	......	....	76.35	....	8.70	266.25	.85	2.5	1.65
3	17[2]	42	65.4	122.90	7.20	38.30	2.35	10.30	246.45	.85	2.7	1.70
4	17[3]	42	166.6	......	....	71.95	....	9.10	247.65	1.05	1.3	3.20

[1]Total does not include grit, oyster shells and charcoal.
[2]One capon died at end of 3rd week and one at end of 4th week.
[3]One capon died at end of 5th week.

Table IX gives the amounts of the various feeds and other materials consumed by the different lots during the experiment. Table X shows the feed consumed per bird by weekly periods. It is interesting to note that in both cases the lots receiving the greater variety of feeds consumed slightly more beef scrap than did those

that received only corn and ground corn in addition to the beef scrap. It will also be observed that the birds in Lot 1 consumed 147.8 pounds of corn and 79.15 pounds of wheat while those in Lot 3 consumed only 65.4 pounds of corn and 122.9 pounds of wheat.

TABLE X. Average feed consumed per capon by weekly periods.

Date	Lot 1 Ration: Corn, wheat, oats, ground corn, bran and beef scrap	Lot 2 Ration: Corn, ground corn and beef scrap	Lot 3 Ration: Corn, wheat, oats, ground corn, bran and beef scrap	Lot 4 Ration: Corn, ground corn and beef scrap
	Lbs.	Lbs.	Lbs.	Lbs.
Dec. 12-18	3.104	3.169	.....	.....
Dec. 19-25	2.750	2.800	.....	.....
Dec. 26-Jan. 1	2.642	2.568	2.615	2.465
Jan. 2-8	2.562	2.106	2.706	2.635
Jan. 9-15	2.623	2.712	2.647	2.632
Jan. 16-22	2.465	2.454	2.528	2.274
Jan. 23-29	2.212	2.204	2.360	2.312
Jan. 30-Feb. 6	2.515	2.477	2.343[1]	2.391[1]

[1]Ending Feb. 5th.

Table XI shows the cost of the various feeds consumed, with prices for feeds as given on page 516. It will be noted that the cost of feed in both cases was lower with the lots receiving the ration made up of corn, ground corn and beef scrap. This difference is greater in the case of Lots 3 and 4, because Lot 3 consumed a considerably larger amount of wheat than did Lot 1. With wheat and corn charged at more nearly the same price per hundredweight, this difference would not be so great.

TABLE XI. Cost of feed consumed.

Lot	Corn	Wheat	Oats	Ground corn	Bran	Beef scrap	Grit	Oyster shells	Charcoal	Total
1	$1.478	$1.187	$ .044	$ .316	$ .029	$ .253	$.006	$ .017	$ .032	$3.36
2	1.812	.....	....	.832	....	.239	.006	.019	.037	2.95
3	.654	1.844	.061	.417	.031	.283	.006	.020	.038	3 37
4	1.666	.....	....	.784	....	.250	.008	.010	.072	2.79

Table XII gives the initial and final weight, gain in weight, and percentage gain of each bird. It will be noted that there was considerable variation in the gain in weight and percentage gain of the different birds. Attention is called to capon No. 1019 in Lot 2 which gained 3.817 pounds or 82.69 percent as compared with No. 1024 in the same lot, which gained 1.45 pounds or 26.53 percent.

Table XIII shows the weight and gain of each lot by weekly periods. While there was a great irregularity in the gains from week to week, it will be observed that the gains became much lower during the latter part of the experiment.

TABLE XII.

Lot 1—Various feeds—57 days					Lot 2—Corn and beef scrap—57 days				
Capon No.	Av. initial weight	Av. final weight	Gain	Percentage gain	Capon No.	Av. initial weight	Av. final weight	Gain	Percentage gain
	Lbs.	Lbs.	Lbs.	Percent		Lbs.	Lbs.	Lbs.	Percent
1003	5.300	8.316	3.016	56.91	1000	5.050	7.683	2.633	52.14
1004	5.883	8.516	2.633	44.78	1001	4.366	6.483	2.117	48.49
1005	5.533	8.550	3.017	54.55	1002	4.250	6.483	2.233	52.54
1006	4.683	7.016	2.333	49.82	1007	5.483	7.633	2.150	39.21
1008	4.616	6.133	1.517	32.86	1009	5.833	7.700	1.867	32.01
1012	3.366	5.150	1.784	53.00	1010	5.200	7.433	2.233	42.94
1014	5.300	8.083	2.783	52.51	1011	4.050	6.366	2.316	57.18
1015	4.116	6.166	2.050	49.80	1013	4.350	6.383	2.033	46.74
1016	4.583	6.600	2.017	44.01	1017	4.566	7.533	2.967	64.98
1018	4.983	6.916	1.933	38.79	1019	4.616	8.433	3.817	82.69
1020	4.350	6.666	2.316	53.24	1023	5.516	7.716	2.200	39.88
1021	5.033	7.900	2.867	56.96	1024	5.466	6.916	1.450	26.53
1022	5.850	8.283	2.433	41.59	1025	4.983	7.416	2.433	48.83
Total....	63.600	94.300	30.700	48.27	Total	63.730	94.180	30.450	47.78
Lot 3—Various feeds—42 days					**Lot 4—Corn and beef scrap—42 days**				
903	7.116	8.866	1.750	24.59	901	5.600	7.383	1.783	31.84
904	5.633	7.083	1.450	25.74	902[3]	5.916	7.900	1.984	33.54
907	5.000	6.150	1.150	23.00	905	4.883	6.600	1.717	35.16
909	6.483	7.266	0.783	12.08	906	5.183	6.750	1.567	30.23
910	5.766	6.600	0.834	14.46	908	7.016	8.233	1.217	17.35
911	5.683	7.716	2.033	35.77	912	5.066	6.733	1.667	32.91
916	5.633	7.083	1.450	25.74	915	3.516	4.850	1.334	37.94
918	4.433	5.883	1.450	32.71	913	6.950	8.316	1.366	19.65
920	4.366	5.800	1.434	32.84	917	5.483	6.533	1.050	19.15
921[1]	6.350	7.600	1.250	19.69	919	5.583	6.500	0.917	16.42
925	4.966	6.016	1.050	21.14	922	4.600	6.666	2.066	44.91
926[2]	5.416	6.250	0.834	15.40	923	6.166	7.800	1.634	26.50
929	7.166	8.966	1.800	25.12	924	4.583	6.083	1.500	32.73
930	6.133	7.600	1.467	23.92	927	6.250	7.783	1.533	24.53
932	5.250	7.716	2.466	46.97	928	5.266	7.050	1.784	33.88
934	4.883	5.700	0.817	16.53	931	4.338	5.283	0.950	21.92
935	4.616	6.666	2.050	44.41	933	6.700	8.650	1.950	29.10
Total....	94.900	118.970	24.070	25.36	Total	93.100	119.120	26.020	27.95

[1]In test 28 days. [2]In test 21 days. [3]In test 35 days.

TABLE XIII. Weekly weights and gains

Date	Lot 1—Various feeds—13 capons				Lot 2—Corn and beef scrap—13 capons			
	Weight		Weekly gain		Weight		Weekly gain	
	Total	Av. per capon	Total	Av. per capon	Total	Av. per capon	Total	Av. per capon
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Dec. 11, 12, 13	63.60	4.892	....	....	63.73	4.902	....	....
" 19	69.15	5.319	5.55	.427	69.85	5.373	6.12	.471
" 26	75.00	5.769	5.85	.450	75.50	5.808	5.65	.435
Jan. 2	80.05	6.158	5.05	.388	79.05	6.081	3.55	.273
" 9	84.20	6.477	4.15	.319	83.15	6.396	4.10	.315
16	86.55	6.658	2.35	.181	86.60	6.661	3.45	.265
23	90 10	6.931	3.55	.273	89.95	6.919	3.35	.258
30	92.40	7.108	2.30	.177	91.70	7.054	1.75	.135
Feb. 6, 7, 8	94.30	7.254	1.90[1]	.146[1]	94.18	7.245	2.48[1]	.191[1]
	Lot 3—Various feeds—17 capons				**Lot 4—Corn and beef scrap—17 capons**			
Dec. 25, 26, 27	94.90	5.582	....	....	93.10	5.476	....	....
Jan. 2	99.50	5.853	4.60	.271	98.15	5.774	5.05	.298
" 9	106.40	6.258	6.90	.405	104.15	6.126	6.00	.352
" 16	111.00	6.529	4.60	.271	108.20	6.365	4.05	.239
" 23	108.50[2]	6.781	3.75	.236	113.05	6.650	4.85	.285
" 30	103.05[3]	6.870	2.15	.143	116.75	6.868	3.70	.218
Feb. 5, 6, 7	105.12	7.008	2.07	.138	111.22[4]	6.951	2.37	.148

[1] This gain is for eight days. [2] No. 926 taken out January 16, weight 6.25 lbs.
[3] No. 921 taken out January 23, weight 7.6 lbs. [4] No. 902 taken out January 30, weight 7.9 lbs.

Table XIV gives a summary of the experiment. Very little difference is shown in the gains produced by the two rations. Lots 1 and 2 made almost exactly the same gain, while Lot 4, getting corn, ground corn and beef scrap, gained approximately 2 pounds or 8.1 percent more than Lot 3, which received the greater variety of feeds.

TABLE XIV. Summary.

Lot	Ration	Gain	Feed consumed	Feed consumed per lb. gain	Cost of feed[1]	Cost of feed per lb. gain
		Lbs.	Lbs.	Lbs.		Cents
1	Corn, wheat, oats, ground corn, bran and beef scrap	30.70	271.35	8.83	$3.36	10.95
2	Corn, ground corn, beef scrap	30.45	266.25	8.74	2.95	9.67
3	Corn wheat, oats, ground corn, bran and beef scrap	24.07	246.45	10.24	3.37	14.02
4	Corn, ground corn, beef scrap	26.02	247.65	9.17	2.79	10.71

[1]See page 516 for a list of prices of feeds.

The feed consumed per pound of gain by Lots 1 and 2 was almost the same, but Lot 3 consumed slightly over a pound more feed per pound of gain than did Lot 4. The more important difference in this experiment is in the cost of feed per pound of gain, on account of some of the feeds which Lots 1 and 3 received being higher priced, under usual market conditions, than is corn, which constituted the chief part of the ration that was fed to Lots 2 and 4. The last column in Table XIV shows the difference in cost of feed per pound of gain. It will be noted that the cost per pound of gain with Lot 1, receiving the variety of feeds, was slightly more than 1 1-4 cents higher than with Lot 2, fed corn and beef scrap, while the gain produced by Lot 3 cost nearly 3 1-3 cents per pound more than did that produced by Lot 4. The higher cost of production with Lots 3 and 4 than with Lots 1 and 2, respectively, is probably due, in part at least, to the fact that the birds in Lots 3 and 4 were less vigorous than those in Lots 1 and 2. The reason for the greater variation in feed cost per unit of gain between Lots 1 and 3 than between Lots 2 and 4 is not apparent.

Figs. 1 and 2 show the capons used in Lots 1 and 2, respectively, after being dressed ready for packing. There was very little, if any, difference noticeable in the market quality of the dressed birds from the two lots, but those from Lot 2, which received corn, ground corn and beef scrap, had a yellower skin than did those from Lot 1. These illustrations show the manner in which the head and neck are wrapped for packing. This method of wrapping adds to the appearance of the dressed birds.

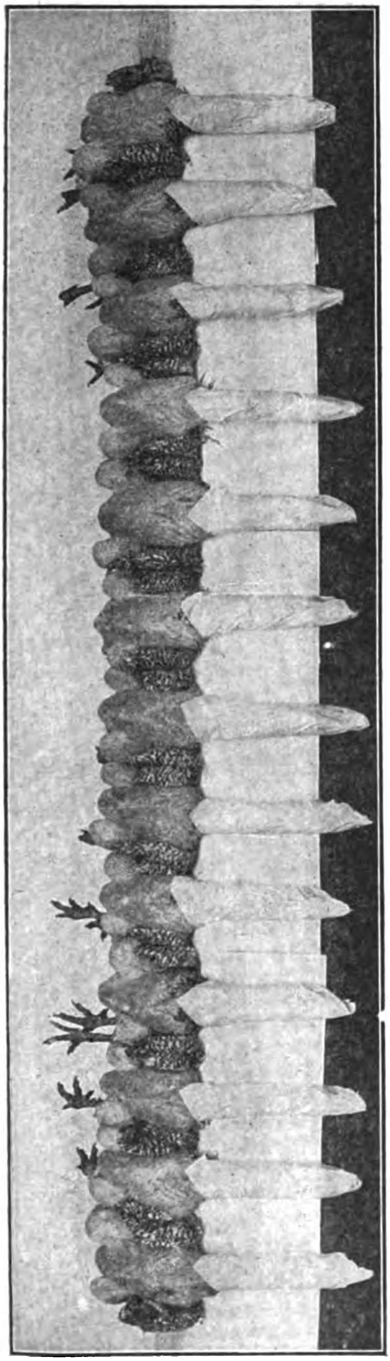

Fig. 1.—Capons used in Lot 1.

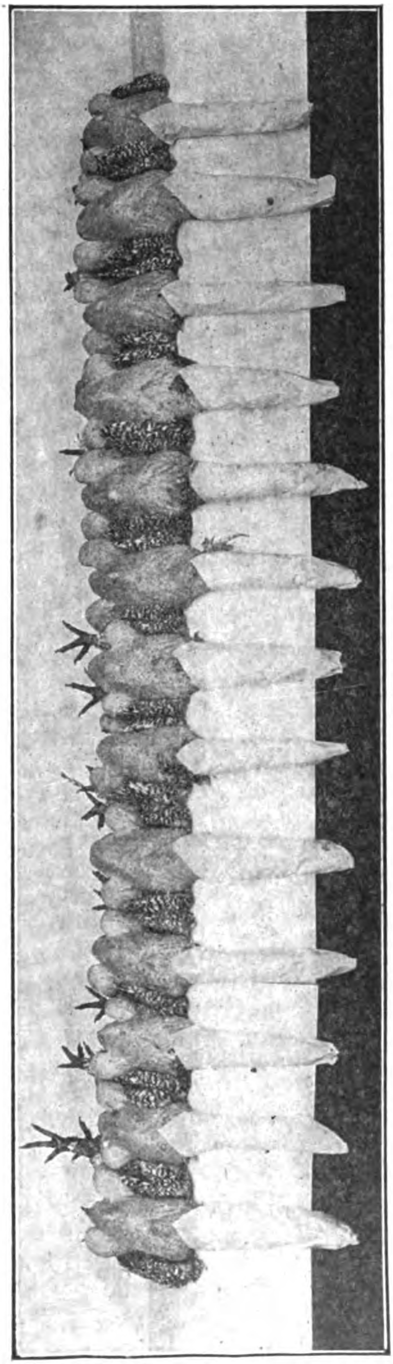

Fig. 2.—Capons used in Lot 2

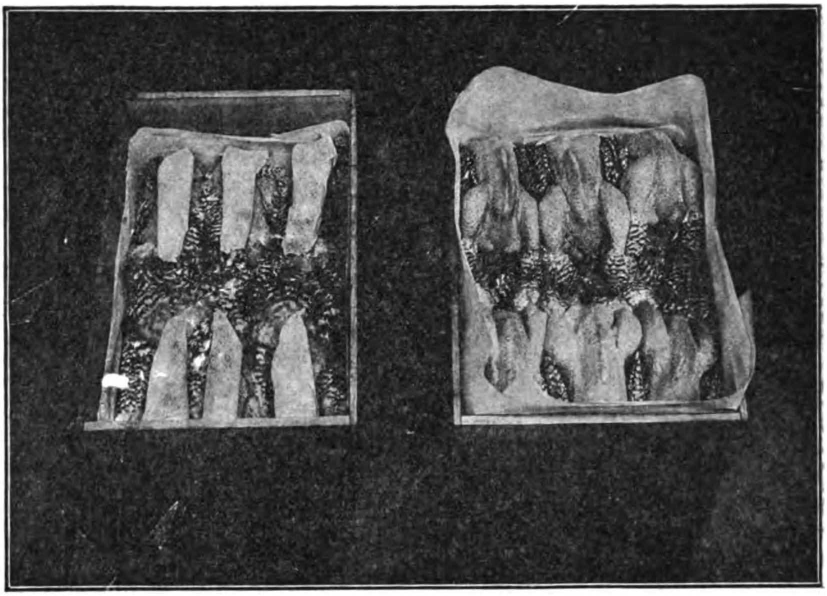

Fig. 3. Showing method of packing capons in boxes.

The box to the left in Fig. 3 shows one layer of six birds in place. The breasts are placed down with the heads and feet up. The box is lined with waterproof paper and a layer of this paper is placed over the birds in the bottom of the box before the rest are placed in position. The other box in Fig. 3 is packed full ready to be covered with paper and closed for shipment. The birds in the second layer are placed with breasts up and heads and feet down. By packing in this way, the birds show to good advantage, no matter from which side the box is opened.

The illustrations on the opposite page show the difference in appearance of a cockerel, capon and slip. The cockerel, at the top, shows his truly masculine characteristics, while the capon, in the center, shows practically no masculinity. The growth of the comb and wattles ceases when the operation is performed, although the growth of the plumage is considerably heavier than on the cockerel. The capon does not have the alertness of the cockerel but is more quiet and even sluggish in movements. The slip, at the bottom, is the result of an unsuccessful operation. Part of the testicle is not removed, and on this account the bird develops, and in appearance resembles the cockerel. Some slips develop sex character to such an extent that they may be mistaken for cockerels.

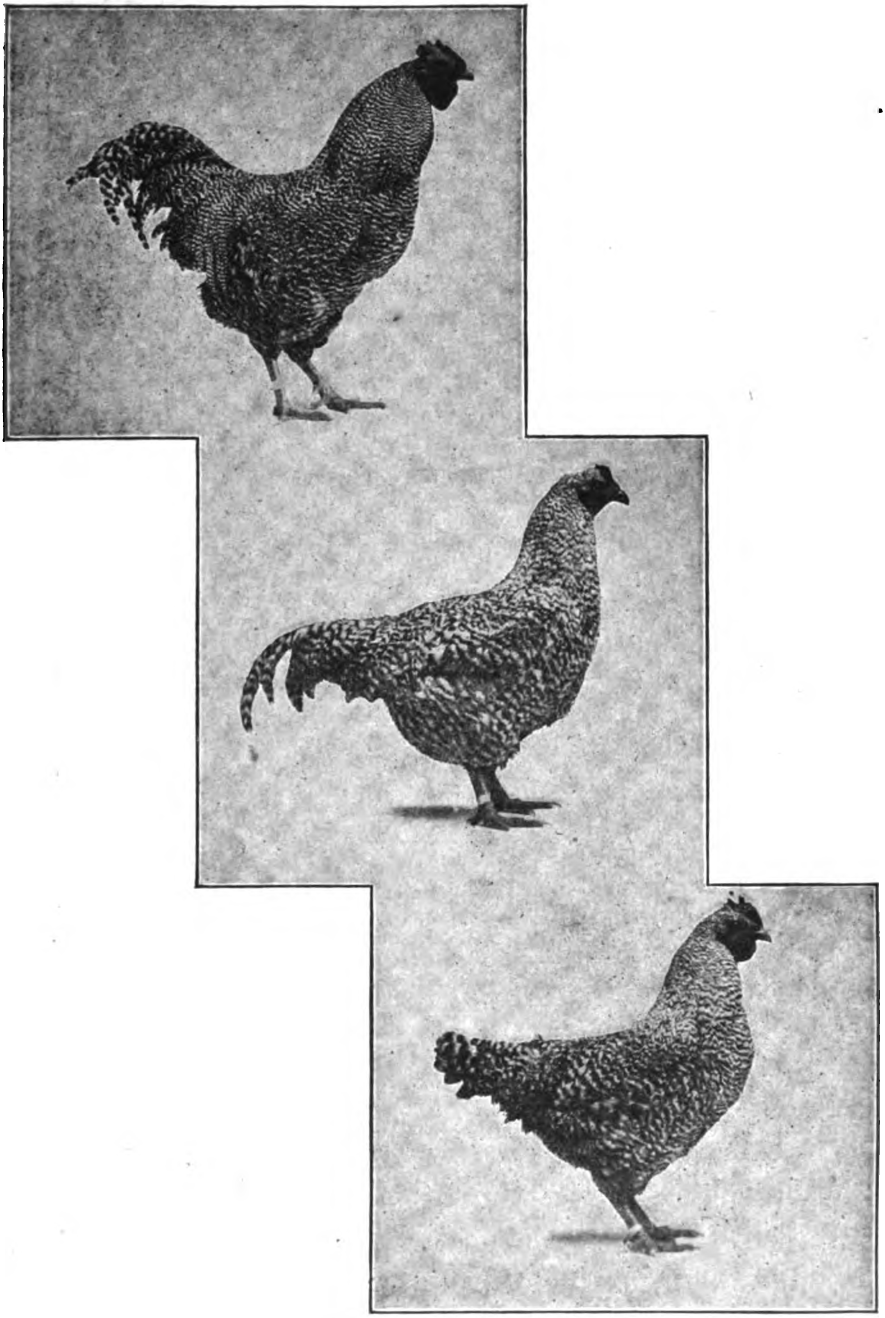

Fig. 4. Appearance of cockerel, capon and slip.

Anyone wishing information on caponizing is referred to Farmers' Bulletin 452, which may be secured from the U. S. Department of Agriculture, Washington, D. C., and to the printed directions that are furnished with caponizing instruments.

FERTILITY OF EGGS

LENGTH OF TIME, AFTER MATING, REQUIRED FOR EGGS TO BECOME FERTILE

The study of the fertility of eggs was begun in 1911 and continued in 1912. In 1911, three pens of Leghorns and three pens of Rocks were used, and in 1912, thirteen pens of Rocks were used in the test to determine the time which elapses after mating before fertile eggs are laid. All eggs laid after mating were used during the test conducted in 1911, and all those laid after the first day, during the 1912 test.

In this work, one male was mated with a pen of 12 to 15 females. Except for the two pens of Rocks hatched in 1909, that were mated in 1912, with which yearling male birds were used, the male birds used were cockerels.

TABLE XV. Sterile and fertile eggs laid.

Date males were placed in pens		Eggs laid each day after males were placed in pens															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Three pens of Rocks, hatched in 1909																	
March 9, 1911 3:30 p. m.	Sterile	5	6	4	4	1	2	1	1	3	1	3	1	0	5	2	1
	Fertile	0	2	0	7	4	5	9	7	7	8	7	9	11	11	9	10
Three pens of Leghorns, hatched in 1909																	
March 9, 1911 3:30 p. m.	Sterile	3	5	4	1	3	2	1	1	1	2	0	1	0	1	1	0
	Fertile	0	3	2	8	9	13	11	11	9	16	12	8	14	8	15	14
Two pens of Rocks, hatched in 1909																	
March 6, 1912 3:00 to 4:00 p. m.	Sterile	..	5	4	2	2	3	1	1	0	1	1	1	0	1	0	1
	Fertile	..	1	3	3	3	4	3	6	7	4	8	7	6	8	7	5
Eleven pens of Rocks, hatched in 1911																	
March 6, 1912 3:00 to 4:00 p. m.	Sterile	..	62	62	38	39	37	31	27	20	19	13	18	11	15	11	10
	Fertile	..	7	13	26	35	49	45	44	67	61	44	68	68	59	73	61

The eggs which were candled out and those which remained in the incubator unhatched after the chicks were taken out, were broken in order to correct any mistakes which might have been made in candling.

In using the terms fertile and sterile, or the abbreviations F and S, it should be understood that the eggs designated as fertile are those in which the embryo developed sufficiently to be detected without the aid of a microscope. All others are marked sterile.

Table XV shows the results secured in this test from 19 pens, approximately 230 fowls. It gives the number of fertile and sterile eggs laid on each day after mating, including the sixteenth. In the first three divisions of the table, it is seen that the fertility was at its best on and after the seventh day. In the last division of the table, which deals with Rock pullets, the fertility was not at its height until the twelfth.

LENGTH OF TIME AFTER MATING WAS BROKEN THROUGH WHICH FERTILE EGGS WERE LAID

Sixteen pens of fowls were used in the study of this phase of the fertility of eggs. In 1911, three pens of Rocks and three pens of Leghorns, and in 1912, ten pens of Leghorns were used in this work.

Table XVI shows the number of fertile and sterile eggs laid each day after mating was broken. It is noted that, in the first division of the table, the number of fertile eggs laid does not decrease until the twelfth day and that one fertile egg was laid on the twentieth day after the mating was broken. In the second and third divisions of the table, the number of fertile eggs decreases after the ninth day and in the last one the decrease starts after the eighth day. Judging from the results of this test, it would be safe to use eggs for hatching from pens for at least one week after the male bird is removed.

TABLE XVI. Sterile and fertile eggs laid after mating was broken

Date mating was broken		Eggs laid each day after mating was broken: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Three pens of Rocks, hatched in 1909																						
August 21, 1911 2:00 p. m.	**Sterile**	1	0	2	0	2	1	2	5	2	3	4	2	8	10	5	10	8	10	11	9	9
	Fertile	12	9	9	6	12	11	10	11	8	10	10	6	6	3	3	1	1	2	0	1	0
Three pens of Leghorns, hatched in 1909																						
August 21, 1911 2:00 p. m.	**Sterile**	1	1	0	2	0	2	1	5	4	7	6	8	8	12	13	10	14	13	14	12	13
	Fertile	17	17	15	18	16	11	16	15	10	9	9	10	4	2	2	0	0	2	0	0	0
Two pens of Leghorns, hatched in 1909																						
April 29, 1912 1:30 p. m.	**Sterile**	3	2	0	1	0	4	3	4	4	7	6	8	13	14	18	24	15	19	21	17	15
	Fertile	15	16	20	14	19	18	15	16	18	15	13	6	6	4	3	3	1	0	0	0	0
Eight pens of Leghorns, hatched in 1911																						
April 29, 1912 1:30 p. m.	**Sterile**	4	5	7	2	10	7	5	6	10	18	21	37	28	47	45	60	49	51	48	49	39
	Fertile	64	69	78	77	63	71	73	73	68	58	51	40	32	24	25	12	10	1	4	0	0

INDIVIDUAL MATING

Individual mating was carried on in addition to the foregoing work in order to secure more definite data regarding the time that elapses after mating before fertile eggs are laid, number of fertile eggs produced from one mating and length of time through which fertile eggs are laid. Single Comb White Leghorns were used in this work. Nos. 1-38 were hatched in 1909, the others in 1911.

In doing this work, the male bird was placed with the females and carefully watched. Whenever a hen was mated, her band number and the time of the mating were recorded. All eggs laid during this test were marked with the number of the hen that laid them and the date and hour laid. The eggs were incubated from two to four days and then broken to determine whether they were fertile or sterile.

In all, 46 hens were mated, but 4 of these laid no eggs, and 2 were mated on two different days, so that the following table contains the records of 40 hens. Of this number, 7 were mated more than once on the same day. Table XVII shows the date and hour each hen was mated, whether the eggs laid were sterile or fertile and the hour the first and last fertile eggs were laid. At the bottom of the table is given a summary of sterile and fertile eggs laid on each day after mating.

A study of Table XVII shows that the number of fertile eggs laid did not decrease very rapidly until after the twelfth day. The fertility was rather low throughout the test, due to the fact that seven hens laid no fertile eggs. It is not known whether this lack of fertility in the eggs produced by these hens was the result of imperfect mating or due to some abnormal condition of the hens. Three of these seven hens were in breeding pens in the spring and at that time a good percentage of their eggs were fertile.

Table XVIII shows a summary of the 26 hens, whose records are given in the foregoing table, which had only one mating and laid one or more fertile eggs. This summary gives the time after mating when the first and last fertile eggs were laid and the number of fertile eggs laid. The shortest time after mating in which fertile eggs were produced was about 42 hours—Nos. 38 and 351 both being very near this time. Nos. 309 and 403 laid sterile eggs approximately 48 and 46 hours, respectively, after mating. These were the only cases, however, that the first egg laid 42 hours or more after mating was not fertile.

The length of time after mating through which fertile eggs were produced varied with different individuals from a little less than a week up to nearly 18 days. The results secured in this test when the hens were mated individually and with a single mating were not far different from those secured in regular pen mating, as is usually practiced.

TABLE XVII. Results of individual mating—1912

Hen No.	Date and hour mated	Days after mating																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	August 26, 3:15 P. M.	..	1:00 F	1:00 F	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4	August 23, 3:10 P. M.	S	12:30 F	F	..	F	F	F	F	..	F	F	..	7:30 F	S	S	..	..	S	S	..	S	..
8	August 23, 8:17 A. M.	S	4:00 F	..	F	F	F	..	..	S	S	S	4:00 F	..	S	S	S	S	..	S	S	S	..
15	August 23, 8:45 A. M.	..	10:30 F	F	..	F	..	F	F	..	F	..	F	..	11:00 F	..	S	S	..	S	S	..	S
17	August 27, 3:40 P. M.	S	..	8:00 F	..	..	F	F	..	F	F	..	F	F	..	9:00 F	..	..	..	..	..	..	..
18	August 27, 2:52 P. M.	S	..	8:00 F	F	F	..	F	F	..	..	F	F	S	..	8:00 F	..	S	S	..	..	..	..
20	August 27, 3:00 P. M.	S	..	10:00 F	..	F	..	F	F	..	F	..	10:00 F	..	..	..	..	..	..	..	..	..	..
22	August 27, 3:50 P. M.	S	4-00 F	..	F	F	..	F	F	..	F	..	F	..	10:00 F	..	S	S	..	..	..	..	..
24	August 23, 4:00 P. M.	S	S	S	..	S	S	S	..	S	S	..	S	S	..	S	S	S	..	S	S	..	S
26	August 24, 2:00 P. M.	S	11:00 F	F	..	F	F	..	..	F	F	10-30 F	S	S	S	..	..	S	S	..	S	..	S
27	August 24, 2:12 P. M.	S	..	S	..	S	..	..	S	S	..	S	S	..	S	S	..	..	S	..	S	..	..
31	August 27, 3:45 P. M.	S	2:00 F	..	..	F	..	F	..	F	S	..	1:00 F	..	S	..	..	..	..	..	..	..	..
35	August 23, 3:15 P. M.	S	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
38	August 23, 4:10 P. M.	S	10:30 F	F	..	F	S	S	..	S	F	..	S	S	S	S	..	1:00 F	S	..	S	..	S

TABLE XVII. Results of individual mating—1912. Continued.

Hen No.	Date and hour mated	Days after mating																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
309	August 26, 3.35 P. M.	..	4:00 S	..	1:00 F	..	S	..	..	..	F	..	F	S	..	..	9:00 F	..	..	S	S	..	..
351	August 24, 2:26 P. M.	..	9:00 F	F	..	F	..	..	10:00 F	..	..	S	..	S	..	S	..	S	..	S	..	S	S
356	August 26, 2:50, 4:00	S	..	10:00 F	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
376	August 27, 2:00, 3:30	..	..	..	..	2:00 F	..	F	F	..	F	..	F	4:00 F	..	..	..	S	..	S	..	..	..
377	August 23, 3.20 P. M.	..	4:00 F	..	F	F	..	9:00 F	S	S	..	..	..	S	..	..	..	S	..	S	S	..	S
383	August 26, 3:30 P. M.	S	..	8:00 F	F	..	F	F	F	..	..	..	1:00 F	..	..	..	..	..	..	..	..	..	..
384	August 27, 3:07 P. M.	S	2:00 F	..	F	F	F	..	..	..	F	..	F	F	..	F	1:30 F	..	S	S	..	..	..
393	August 27, 2:12 P. M.	S	..	S	..	..	S	..	S	S	..	..	S	..	..	..	..	..	..	..	..	..	..
397	August 26, 3:40 P. M.	..	..	2:00 F	..	F	F	F	..	F	..	F	..	S	..	..	2:00 F	..	S	..	S	.	..
403	August 28, 10:15 A. M.	..	9:00 S	1:00 F	..	S	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
408	August 28, 9:57 A. M.	..	S	..	S	S	S	..	S	S	S	..	S	..	..	S	..	S	S	..	..	..	..
421	August 28, 9:30, 10:45	..	1:00 F	..	F	F	..	..	F	..	F	F	2:00 F	..	..	S	S	..	S	..	..	..	..
423	August 27, 2:16, 3:22, 4:00	..	10:00 F	..	F	F	..	F	F	..	F	..	F	..	F	1:00 F	..	..	..	..	..	..	..
431	August 27, 2:22, 2:27, 3:35	..	..	..	S	..	..	11:00 F	..	F	..	F	..	F	..	11:00 F	..	S	..	S	..	..	..

TABLE XVII. Results of individual mating—1912. Concluded.

Hen No.	Date and hour mated	Days after mating 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
.448	August 23, 3:21 P. M.	S	..	11:00 F	..	F	..	..	..	F	S	..	S	..	S	..	S	2:00 F	..	S	S	..	..
450	August 26, 3:35 P. M.	S	1:00 F	..	F	S	..	..	9:00 F	S	..	S	S	S	..	S	..	S	S	..	S	..	..
555	August 28, 9:30, 10:30	S	..	1:00 F	..	..	F	..	F	..	..	..	..	11:00 F	..	S	..	S	.	..	..	..	..
558	August 28. 9:40 A. M.	S	..	..	3:00 F	..	F	..	..	..	F	..	F	F	..	S	..	9:30 F	..	S	..	S	..
594	August 28, 9:55, 10:10	..	8:00 S	..	..	..	S	..	4:00 F	..	F	F	..	..	S	4:00 F	..	S	S	..	..	..	..
595	August 28, 9:15 A. M.	..	S	..	..	..	..	..	S	..	S	..	..	S	..	S	..	S	..	..	..	..	..
620	August 26, 3:55 P. M.	S	..	8:00 F	F	..	F	S	F	..	F	F	F	..	F	F	2:00 F	..	S	S	..	S	..
626	August 27, 3:20 P. M.	S	..	..	..	3:00 F	..	F	F	..	S	..	..	F	3:00 F	..	S	..	S	S	..	..	..
630	August 27, 4:10 P. M.	S	2:00 F	..	F	S	..	F	..	F	..	..	F	..	..	2:00 F	..	S	..	S	..	..	..
640	August 27, 4:01 P. M.	S	..	S	..	S	S	..	..	..	..	S	..	S	S	..	S	..	S	S	..	..	..
645	August 27, 3:11 P. M.	S	..	..	11:00 F	F	..	F	..	..	F	..	..	8:00 F	..	..	S	..	..	..	..	..	..
666	August 24, 3:15 P. M.	S	4:00 F	..	F	F	..	F	..	F	..	..	F	1:00 F	..	..	S	..	S	S	..	S	..
	Total fertile	0	16	16	15	20	10	17	15	8	16	8	17	10	5	8	4	3	0	0	0	0	0
	Total sterile	28	6	4	2	7	7	3	5	8	7	5	8	11	9	12	10	16	15	17	11	6	6

TABLE XVIII. Summary of the individual mating of 26 hens.

Hen No.	Time[1] after mating when first fertile egg was laid		Time[1] after mating when last fertile egg was laid		Total number of fertile eggs laid
	Days	Hours	Days	Hours	
1[2]	1	22	2	22	2
4	1	21	12	16	9
8	2	8	12	8	5
15	2	2	14	2	8
17[2]	2	16	14	17	8
18	2	17	14	17	8
20[2]	2	19	11	19	6
22	2	0	13	18	8
26	1	21	10	21	7
31	1	22	11	21	5
38	1	18	16	21	5
309	3	21	15	17	4
351	1	19	7	20	4
377	2	1	6	18	4
383[2]	2	17	11	22	6
384	1	23	15	23	9
397	2	22	15	22	7
403[2]	3	3	3	3	1
448	2	20	16	23	4
450	1	21	7	17	3
558	4	5[3]	17	0	6
620	2	16	15	22	10
626	5	0[3]	14	0	5
630	1	22	14	22	6
645	3	20[3]	12	17	5
666	2	1	12	22	7

[1]Eggs were gathered every hour, so the time given in this table is only approximately correct.
[2]These hens stopped laying before sterility was established.
[3]These were first eggs laid after first day following mating.

POULTRY BUILDINGS AT OHIO EXPERIMENT STATION

W. J. BUSS

LAYING HOUSE

On the next page is shown an illustration of the laying house that is being used at this Station. This house is 24 ft. x 100 ft. in size. It is divided into six pens, each 15 ft. x 24 ft., and a feed room, 10 ft. x 24 ft. The feed room is located in the center of the house. Partitions of matched sheathing divide the feed room from the pens. Partitions of 2-inch mesh poultry netting are used to divide the pens.

A concrete foundation wall is used under the house. A tile drain was laid in the outside bottom of the trench dug for the wall. No wooden sills are used on the concrete wall. The studs are fastened to the wall by means of an iron pin placed in the bottom of each and in the concrete wall.

No artificial floors are used in the pens. A concrete floor is used in the feed room. On ground that is not well drained, artificial floors would probably be needed to prevent the pens from becoming damp.

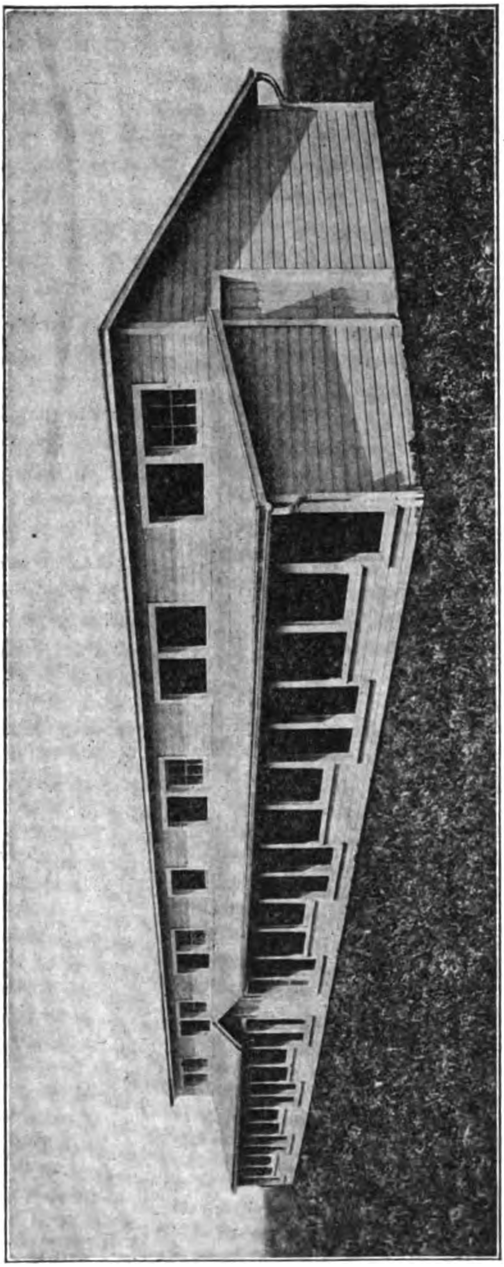

Fig. 5. Laying house at Ohio Experiment Station.

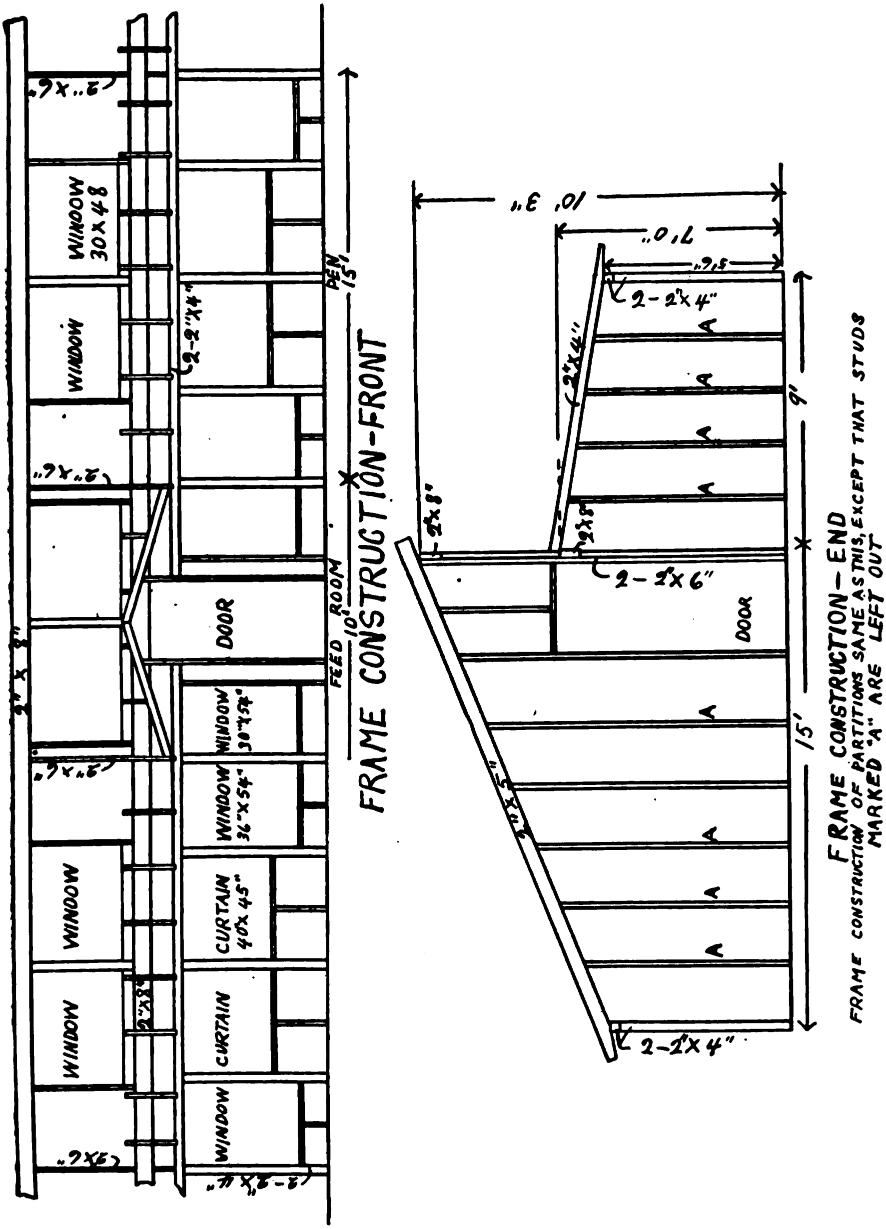

Fig. 6. Frame construction of laying house.

The arrangement and dimensions of doors, windows and curtains are shown in Figs. 5 and 6. The deeper openings shown in the front of the house in Fig. 5 are fitted with windows; the shallower ones, with curtains. The curtain frames are made of 1 in. x 4 in. strips, nailed together at the corners. These frames are covered with a very thin grade of muslin. Two doors in the rear of each pen near the eaves are not shown in the illustrations. These are 20 inches high and 45 inches long. All windows and curtained openings and openings for the doors in the rear of the house are closed with 1-in. mesh wire netting. This netting in one of the curtained openings in each pen is fastened to a removable frame, which makes a convenient place through which to put straw into the pens and remove the litter.

The windows in the upper part of the house are hinged at the bottom to swing in. The curtains and windows in the front of the house are hinged at the top to swing in. The doors in the rear wall of the house are hinged at the top to swing out. Probably a more convenient arrangement for these would be to hang them to swing in.

The walls of the house are of a single thickness of matched siding. The roof is made by laying one thickness of matched sheathing on the rafters and covering this with one of the better grades of prepared composition roofs, of which a number are on the market.

The arrangement of the various appliances in the pens and feed room is shown in the drawings on page 541. The trap nests are placed under the droppings boards.

The size of material used in this house, as shown in the drawings, seems to be satisfactory for this location. Where wind pressure or snow fall differ from what they are here, some variation in size of lumber might be advisable. The framing material in the house is of oak. The siding and sheathing for the roof are of yellow pine.

A house of this type, of a size to accommodate the desired number of fowls, should prove satisfactory in places having the same latitude as Ohio, and probably even farther north or south. This house has been found especially satisfactory during hot weather. In colder climates the windows in the upper part of the house could probably well be double-glazed to prevent radiation to a considerable extent. It might appear, at first sight, that the cost of construction of a house of this type would be greater than that of a shed roof house of the same dimensions. It will be found, however, that there will be very little, if any, difference in the cost, when both houses are built of the same grade of material.

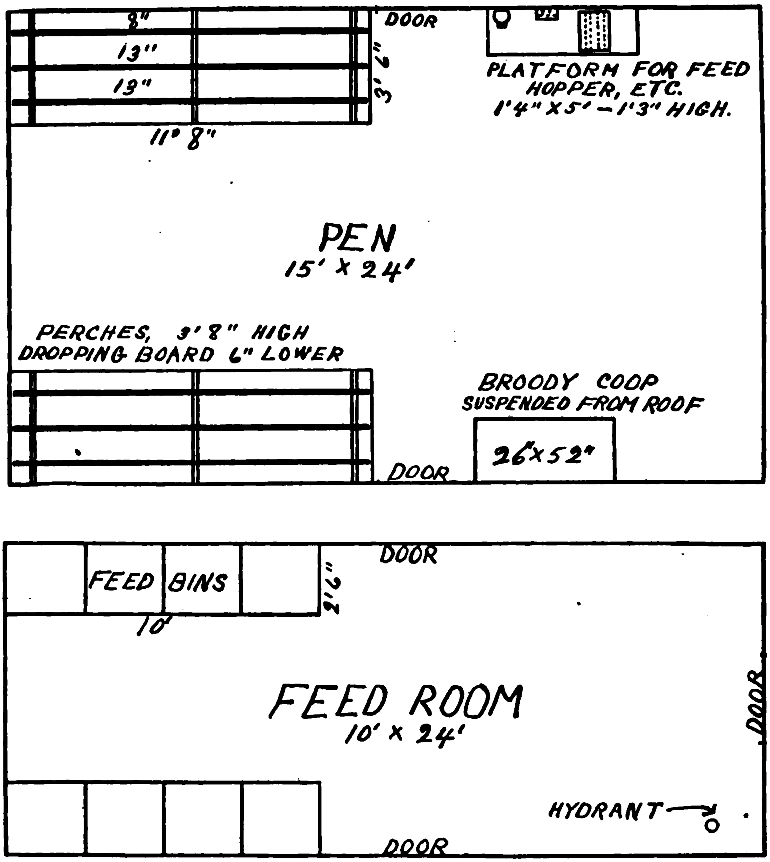

Fig. 7. Plan of pen and feed room in laying house.

COLONY HOUSE

The type of colony house that is being used at this Station is illustrated in Fig. 8. This house is 10 ft. x 12 ft. in size. It is 8 feet high in front and 5 feet, 6 inches high in the rear. The house is divided from front to rear into two pens, each 6 ft. x 10 ft. in size. The perches are placed along the back wall of the house.

The windows and the curtained openings in the house are each 2 ft. 4 in. x 3 ft. 4 in. The windows and curtains are hinged at the top to swing in. A door 2 ft. 4 in. x 5 ft. 10 in. is placed in each end of the house. Two small doors, 9 x 24 inches, are placed near the eaves in the rear wall of the house. These are hinged at the bottom to swing in. The windows are placed in the two openings nearer the center of the house so the sunshine will fall upon the pen floor during the early forenoon and late afternoon in winter rather than upon the walls of the house, as would be the case if they were placed in the outer openings.

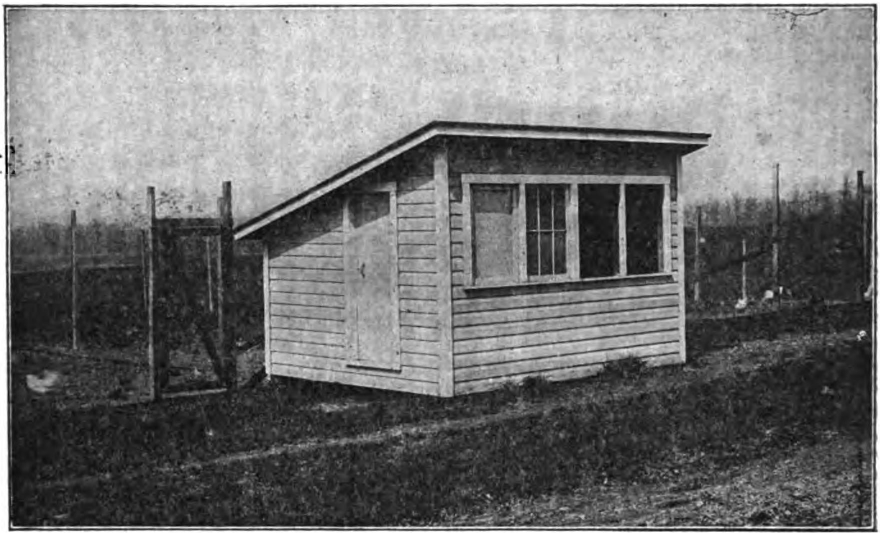

Fig. 8. Colony house.

These houses, as used at this Station with walls constructed of a single thickness of matched siding, are very satisfactory for use during spring, summer and autumn, but some trouble has been experienced during extremely cold weather from frozen combs, especially with Leghorns. With houses built deeper than those in use here, to accommodate larger flocks, this difficulty would be overcome to some extent. Double boarding the rear wall and the roof over the perches would also aid in making the house warmer.

For housing small breeding flocks and growing stock, especially where it is desired to move them frequently in orchards or over comparatively rough land, houses somewhat smaller than the one described above would perhaps be more desirable. A low-wheeled wagon has been constructed especially for moving the colony houses in use here, and with this and a team of horses they can be readily moved over relatively smooth ground, but where conditions as mentioned above exist, smaller houses would doubtless prove more satisfactory.

THIRTY-SECOND ANNUAL REPORT
FOR 1912-1913
PRESS BULLETINS—INDEX

OHIO
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WOOSTER, OHIO, U. S. A., JULY, 1913.

BULLETIN 263

Thirty-Second Annual Report

OF THE

Ohio Agricultural Experiment Station

For the Year ending June 30, 1913

Published by order of the State Legislature

WOOSTER, OHIO
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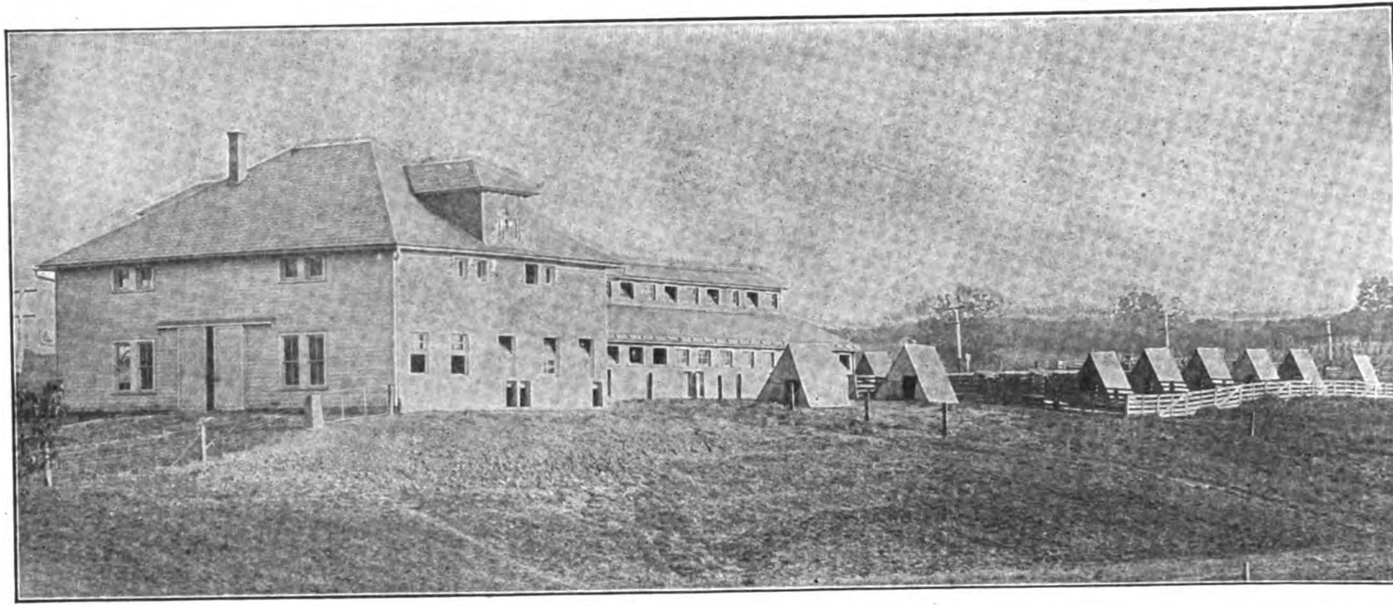

Swine feeding barn and individual houses

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[1]In cooperation with Bureau of Plant Industry, U. S. Department of Agriculture.
[2]In cooperation with Boys' Industrial School. [3]In cooperation with Ohio State Reformatory.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 264 OCTOBER, 1913

ORCHARD BARK BEETLES AND PIN HOLE BORERS

BY H. A. GOSSARD

SUMMARY OF IMPORTANT CONCLUSIONS

1. Several species of beetles make shot-holes or pin-holes in the trunks and branches of fruit trees. Some of these same insects burrow into young twigs at bases of buds. The holes in the trunk and branches may penetrate into the heartwood, or they may spread out into many channels and ramifications in the cambium or sapwood. The most dangerous species are those which mine in the sapwood, and are, therefore, true bark beetles.

2. Some kinds of trees, such as peach and cherry, exude large quantities of gum through the openings in the bark made by the beetles, and the surface of the bark may become coated over with pints to gallons of gum, depending upon the severity of the attack and the size and vigor of the trees. Again, such trees as apple and pear do not gum at all when attacked.

3. Trees that are in an unhealthful or weakened condition are most apt to be attacked. However, both the Fruit Bark Beetle (*Eccoptogaster rugulosus*) and the Peach Bark Beetle (*Phloeotribus liminaris*), the two most destructive species, burrow into the bark of healthy trees in the fall to feed, or in case of the latter species, to construct hibernation cells, and from these holes gum may exude in great quantity the succeeding season. By repeatedly attacking healthy trees in this manner for two or three successive seasons, the beetles are apt to weaken them to such extent that they are suitable for sustaining larvae, and the eggs are then laid in specially constructed burrows. The larvae, mining the sapwood in all directions, will, if numerous, kill a tree in a very brief period. So long as a tree is able to exude gum plentifully, there is hope for its recovery. The gum exuding into the burrows chokes the passages, rendering them uninhabitable by the beetles or young.

Plate I. Peach tree gumming from attack of Fruit Bark Beetle (*Eccoptogaster rugulosus*).

4. There are two broods per season of the Fruit Bark Beetle (*Eccoptogaster rugulosus*), the adults of the first brood appearing during the latter half of May, and in maximum numbers during the first half of June, the brood being practically over by that time, though a few females linger for a month longer. Eggs are laid in a few days after the appearance of the females and hatch in 3 or 4 days. Each female deposits from 30 to over 100 eggs, with an average of about 75 to 90. The larvae mature in 30 to 36 days after hatching and pupate in the burrows. The pupal period lasts from 7 to 10 days, and the beetles of the second brood commence to appear about the middle of July and continue to issue until late August or early September. Some of the beetles of this brood may linger until late October. The progeny of this brood hibernate as larvae in the bark and develop into the early brood of beetles the next May and June.

5. The Peach Bark Beetle (*Phlocotribus liminaris*) hibernates in the beetle form in special cells in the bark, becoming active in late March and early April. The beetles at once commence excavating burrows in dead or living wood, but use only dead or dying wood for incubation burrows. They commence laying eggs about the 20th of April, and each female will, under normal conditions, deposit from 80 to 160 eggs. These eggs hatch in a few days and the larvae require 25 to 30 days to become grown. The pupal period extends over 4 to 10 days, and the beetles of the summer brood appear about the middle of July, maximum emergence occurring during the latter part of August. Beetles continue to appear irregularly until October. The progeny of this brood of beetles are larvae during the fall months and mature as beetles upon the approach of cold weather, but do not leave their hibernation cells until the following spring.

6. The external opening to the burrows of the two species of bark beetles, *Eccoptogaster rugulosus* and *Phloeotribus liminaris*, may be distinguished from each other by the openings to the burrows of the latter being partly filled or covered over with exuded particles, these being held together by a fine, silken web, which is not true of openings made by the former. The engraving work of the two species is also quite different. The main burrow of *E. rugulosus* extends approximately parallel with the axis of the trunk or branch in which it is made, and the galleries of the young larvae branch out from this at right angles, but because of crowding as the insects increase in size, the galleries commence to slant outward toward the ends of the main burrow, with the result that the engraved area, when completed, is something of an oval. On the other hand, the main burrow of *P. liminaris* is nearly always formed transversely

across the trunk or limb, but is occasionally inclined at an angle of 45 degrees, or less, to the axis of trunk or branch; also a small fork is always formed well toward the inner end of the burrow, commencing where the burrow first touches the sapwood.

7. There are several species of small beetles whose work somewhat resembles that of the two species before mentioned, making small holes through the bark into the heartwood or sapwood, or at the base of the buds into the twigs. However, the methods that are effective for the two most important species will be, in a large measure, successful against all.

8. Probably the most important measure to prevent multiplication of all these beetles is to promptly burn all prunings, dead wood and dying trees.

9. Attacked orchards can be successfully reclaimed from attack by cultivation, by liberal fertilization with barnyard manure and commercial fertilizer, and by whitewashing or spraying with carbolized soapy mixtures. (See page 48.)

10. Treatment should commence in the spring. Prune severely, spray before the leaves appear, and apply a heavy coat of whitewash to the trunks and larger branches in early April. Cultivate and fertilize as soon as the ground is in suitable condition; apply a second coat of whitewash or other repellent in early July and a third about the first of September. Apply thick whitewash with a broom; thin mixture may be applied with a spray pump, but should be repeated until a good coating is secured.

ORCHARD BARK BEETLES

INTRODUCTION

Few, if any, insects can more quickly kill a tree than those small beetles known as bark beetles or quite generally as shot-hole borers. The adult beetles make the small openings, resembling shot holes through the outer bark, either to obtain food or to construct brood chambers in which their young can develop. The larvae of the most destructive species make numerous radiating, sinuous galleries through the growing or sapwood, thus attacking the tree in a vital part. Thus, it may happen that a tree will suddenly wilt and die in midsummer before the owner has noticed that it is in any way diseased; however, such an attack generally indicates a low state of vitality, and weakened trees are certain to be the ones first chosen for destruction. Healthy trees are sometimes attacked, but are rarely or never killed within a brief space of time. The most common species is the Fruit Bark Beetle, *Eccoptogaster rugulosus*, often called the Shot Hole Borer. It attacks nearly all species and varieties of orchard fruits. After this species, the Peach Bark

Borer, *Phloeotribus liminaris*, ranks next in importance in Ohio, and, at its worst, this beetle can do as much damage as the first. A few other nearly related species have somewhat similar habits, being known as Pin Hole Borers, but these are of minor importance and are, therefore, given but brief notice in this publication. These Pin Hole Borers make their burrows in the heartwood, but the external openings through the bark resemble the exit holes of the Shot Hole Beetles, except that they are smaller.

Following the devastation wrought a few years since by San Jose scale upon peach orchards situated along the shore of Lake Erie, came an outbreak of bark beetles, which not only threatened the destruction of all uncared for and diseased trees, but menaced valuable and healthy orchards as well. When this outbreak was first brought to the attention of the Experiment Station, the Department of Entomology was unable, with its slender resources, to handle the matter alone, since the life history under normal outdoor conditions could only be determined by a man stationed in the infested district, and the resources then at our command permitted the employment of only one assistant. Through the kindness of Dr. L. O. Howard and Prof. A. L. Quaintance, of the Bureau of Entomology, U. S. D. A., Mr. H. F. Wilson was employed by the Bureau and stationed in the infested region during the spring, summer and fall of 1908, working under the joint direction of Prof. Quaintance and the writer, the field expenses being borne by the Station. Mr. Wilson made careful life-history studies of the two species of bark beetles at work and also conducted experiments on a considerable scale to determine the best methods of control. The more important facts regarding their life cycles and habits, as set forth in the following pages were determined by him, and have since been confirmed and added to by a number of other observers, particularly by Mr. J. L. King, who has given us the best records and account of the Fruit Bark Beetle or Shot Hole Borer. Mr. Wilson's work upon the Peach Bark Beetle, *Phloeotribus liminaris*, was put into order and published as a bulletin of the Bureau of Entomology, U. S. D. A.,* according to the terms of cooperation agreed upon between the Bureau and the Experiment Station. The following summer (1909) Mr. L. L. Scott, now of the Bureau of Entomology, U. S. D. A., was stationed at the headquarters formerly occupied by Mr. Wilson and carried on, under the exclusive direction of the Experiment Station, the largest remedial tests that have yet been undertaken against these two species. He also accumulated some additional life history data, relating more especially to *Eccoptogaster*

*Bulletin No. 68, Part IX.

rugulosus, and secured some confirmatory records relating to *Phloeotribus liminaris*. His èconomic conclusions, being based on large tests, and having been confirmed by subsequent experiments and observations through four or five seasons, are adopted as being substantially correct. During the following two seasons, 1910 and 1911, Mr. R. D. Whitmarsh conducted similar experiments, but because of having his headquarters at Wooster and his time being largely claimed by other matters, he was not able to do more than confirm a part of the work of the preceding two years. The past two seasons (1912-1913) Mr. J. L. King has had a laboratory at Gypsum in the Lake District and has devoted his time to investigating a number of the important fruit pests found in this fruit-growing center. Part of his results consist of numerous important records which have been added to the data previously accumulated regarding bark beetles. All photographs and drawings shown in this bulletin and not otherwise accredited were made by Mr. King. Mr. W. H. Goodwin has also contributed to the investigation at different times, having had practical charge for brief periods of the application of the remedies in the field, owing to the sickness or absence of those more immediately responsible for the work. The general planning and outlining of the work has been done by the writer, also much field inspection, and some of the field applications of remedies were made by him.

We are indebted to many residents of the Lake Shore region for substantial aid and cooperation throughout the period of this investigation. Perhaps it is not invidious to make special mention of the courtesies extended and the aid rendered by Mr. W. H. Wright, of Lakeside, and Mr. Wm. Miller, of Gypsum.

THE FRUIT BARK BEETLE

Eccoptogaster rugulosus Ratz.

HISTORY

This insect was first described in 1837 from European specimens and seems to have been first recognized in America in 1878. It was at that time reported to be damaging peach trees in Elmira, N. Y., and its identity was established by referring specimens to the eminent coleopterist, Dr. J. L. Leconte. A few years earlier than this, Dr. C. V. Riley had received the same insect from Williamsport, Maryland, and also from Hillsboro, Missouri, but did not recognize the species. In 1880 it was reported from Fairhaven, New Jersey, and also from Coopersburg, Pa. In 1884 it was reported from Cambridge, Mass. In 1885 and 1886 it was noted as doing considerable damage in North Carolina. It seems to have been established in the west fully as early as in the east. The report of Dr. S. A. Forbes, State Entomologist of Illinois, for the years 1889 and

1890, indicates that it was well scattered over the southern part of that state at that time and must have been present several years before being discovered. In 1888 Prof. J. M. Stedman gave notice to it in Bulletin 44 of the Missouri Agricultural Experiment Station and stated that it was found as far west as Kansas. Prof. V. H. Lowe contributed some observations on the species in Bulletin 180 of the N. Y. State Agricultural Experiment Station. He reported it as having been quite serious in the vicinity of Geneva, and also in Monroe and Niagara counties, N. Y., during the summer of 1900. At the present writing it seems to be distributed over practically all of the territory east of the Mississippi River and spotted over several states west of this stream. The following excerpts from letters of Entomologists residing in these western states doubtless give a fairly accurate record of its present distribution and importance:

Texas: "Quite generally distributed in this state. It occurs in all of our fruit-growing sections in the central and eastern portion of the state, often in very large numbers. It has been abundant in a good many sections for the past ten years."—Professor Wilmon Newell.

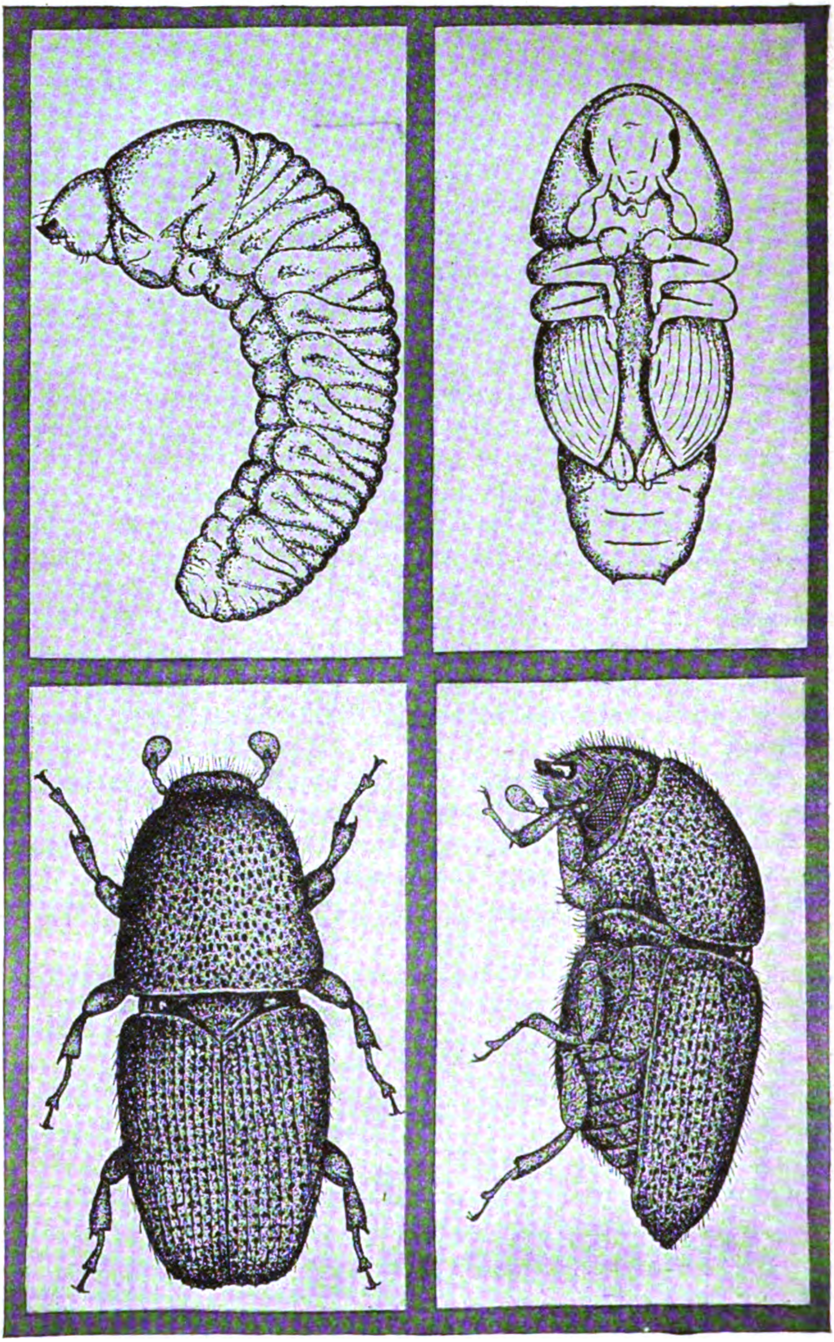
Oklahoma: "*Eccoptogaster rugulosus* not reported before 1897 in this state; at present, it is present in about thirty counties. This beetle does a great deal of damage in this state."—Professor C. E. Sanborn.

Kansas: "First mention that we can find of it is in the Trans. Kan. State Hort. Soc., 1898, by E. A. Popenoe, who states that his first notice of it was in 1897, during nursery inspection. It is now quite common in this state and is quite generally distributed, but is not considered a very serious pest, as the damage is not very heavy."—Professor S. J. Hunter.

"It occurs throughout Kansas wherever there are enough of its food plants growing to support it."—Professor T. J. Headlee.

Nebraska: "This insect has been present in Nebraska for at least six or seven years. While not very abundant, it occurs occasionally in the southeastern counties and, in one or two instances, was found to have completely destroyed several small fruit trees."—Professor Lawrence Brunner.

Iowa: "Occurs in Iowa, occasionally clear to the western border of the state. I have scattered localities across the entire state. It has, in a few instances, done considerable damage locally, although it does not yet seem to be universally enough distributed so that the total harm is very great. I have no record of it, preceding my first finding of it in 1901."—Professor H. E. Summers.



—J. L. King

Plate II. Full grown larva, pupa, and dorsal and side view of beetle of *Eccoptogaster rugulosus*, greatly enlarged.

Minnesota: We find in our collection no specimens of the Fruit Bark Beetle from Minnesota, nor have we received any complaint of this insect. Dr. Lugger, in his Fifth Report, 1899, refers to it as "Not yet found in Minnesota, but uncomfortably near it, etc."—Professor F. L. Washburn.

Arizona: "I have not, during my three years of residence, discovered any evidence whatever of any species of fruit bark beetles here."—Dr. A. W. Morrill.

Colorado: "This insect occurs in the orchards of the Arkansas Valley below Pueblo, but I have never known of it in any other portion of the state. It has not been a serious pest in the Arkansas Valley to the present time."—Professor C. P. Gillette.

Utah: "I have seen no indications of the presence of *Eccoptogaster rugulosus* in this state. I have kept a rather close outlook for the insect."—Professor E. G. Titus.

Montana: "I do not believe this insect occurs in Montana. We have spent much time in the orchards in all parts of the state and have never taken any specimens."—Professor R. H. Cooley.

California: "Personally, I do not know of the occurrence of this beetle in California. However, in order to get reliable data, I have written to Professor H. C. Fall and Professor C. W. Woodworth. Both of these gentlemen state that this beetle does not exist in California."—E. O. Essig, Sec'y State Com. Hort.

Oregon: "*Eccoptogaster rugulosus* is not found in Oregon." — H. F. Wilson, Assist. Entomologist, Experiment Station.

Washington: "Up to the present time, I have never come in contact with this insect in western Washington."—Professor Trevor Kincaid.

Professor T. D. A. Cockerell says that he has no record of the insect's occurrence in New Mexico.

The species was first recorded in Canadian orchards in 1898. Prof. J. M. Swaine, reporting for the Canadian Division of Entomology, says: "The species is common and injurious in the fruit district of Southern Ontario, but has not been reported recently from any other province of Canada and does not appear to occur at all in Quebec province."

The beetle was apparently disseminated over the whole of Ohio by 1895, and was probably introduced several years earlier. Professor Webster gave some notice to it in Bulletin 68 of the Ohio Station. The number of reports by years from Station correspondents as shown by the Station letter copy-books, beginning with 1895, are as follows:

1895—5 reports	1901—0 reports	1907— 3 reports
1896—8 "	1902—0 "	1908— 6 "
1897—3 "	1903—6 "	1909—12 "
1898—4 "	1904—3 "	1910—13 "
1899—1 "	1905—0 "	1911—39 "
1900—5 "	1906—0 "	1912— 7 "

It appears from this table that there have been two periods of unusual abundance, the first about 1895-1900 and the second from 1908 to 1912. The later outbreak may not have been more severe nor more general than the first, as the ratio of the largest number of reports for any year to the total correspondence received by the Department for that year is practically the same. The distribution of the reports, geographically, indicates, without doubt, that the insect occurs in every neighborhood within the state.

DESCRIPTION

Adult beetle: A little less than one-tenth inch (2-3mm.) long and one-third as wide, color black except the tips of the wing covers and lower parts of the legs, these being russet-red. The wing covers are grooved, the depressions being fitted with lines of minute punctures. The posterior margins of the wings have a saw-toothed edge. The body, in general, is covered sparsely with short pale yellowish hairs. The thorax is smooth and shining, showing numerous punctures under a hand lens and is lined along the posterior and lateral borders with a slightly elevated line.

The head is vertical, the antennae or feelers short and strongly clubbed. For the use of professional entomologists, I append by footnote a brief technical description prepared by Mr. J. L. King.* A fuller technical description by Dr. S. A. Forbes can be found in the 17th Report of the State Entomologist of Illinois for 1889 and 1890.

Larva: The larva is a footless grub, cylindrical, whitish, often tinged with pink, transversely wrinkled, with a small or yellowish head. The anterior part of the body, including the thoracic segments, considerably enlarged, the posterior portion gradually tapering to the end and reflexed or bent downward as viewed from above

*Adult. Small beetle 2-3mm. in length, elongate oval in form, pitchy black with feeble reflections. Head globular and hairy, densely punctate above, genae finely striate, epistoma bearded, eyes elongate, mandibles stout, antennae chestnut brown, terminating in a laminate club. Thorax with disk of promotum sparingly hairy and coarsely punctate, sides slightly carinate. Elytra longer than the thorax; tapering slightly and serrate at the tips, surface with punctations in rows appearing as striae, punctations at intervals bearing erect whitish setae. Abdomen reflexed dorsad. Legs dark brown, tibiae, as in all the family relatives, uncinnate at the inner apical angle.

the back. The mouth parts are rusty-reddish, the antennae small, two-jointed and located at the base of the mandibles. When newly hatched, the larvae are only about .56mm. long, but when full grown are from 3.5 to 4mm., or about one-tenth of an inch long.

Pupa: The pupa is a trifle less than one-fourth of an inch (3-3 5mm.) long (measurements taken from formaldehyde specimens) and dull white to slightly pinkish in color. The lower portion of the mandibles and sometimes the tips of the tarsi are brownish. Wing pads grooved, obliquely appressed against sides of abdomen, several segments of abdomen beyond hindermost reach of the pads.

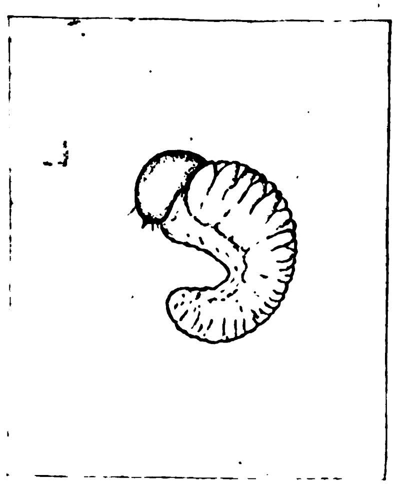


Fig. 1. Young larva, greatly enlarged.

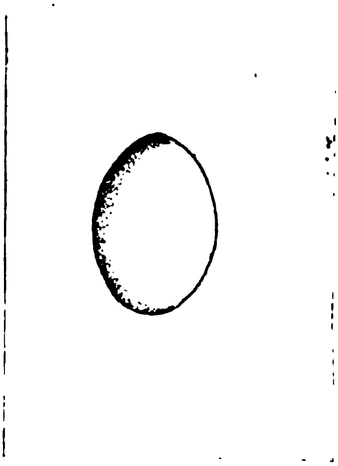


Fig. 2. Egg, greatly enlarged.

Egg: The eggs when first deposited are milky white, later becoming translucent or clear. They are oval in form, about .52mm. in length by .36mm. in width. Mr. Lowe's measurements are practically the same, .574mm. by .4mm. as an average.*

LIFE HISTORY AND HABITS

HIBERNATING LARVAE

At the ends of the larval burrows in dead wood, cells are excavated, generally in the sapwood but sometimes in the outer bark, and in these cells the larvae hibernate, pupating in early May. Larvae in the sapwood cells are apparently mature by the 10th of April and are not feeding, and it is presumed that the majority of these are full fed when they commence hibernating in the fall. Some of those in the outer bark are smaller than the average and have a pinkish

*Bull. No. 180, New York Agricultural Experiment Station, Geneva, N. Y.

tinge. When removed to suitable clean vessels, and left for a few hours, fine filaments of reddish-brown excrement may be found protruding from the ends of the abdomen of these retarded larvae, this, with the pinkish tinge of the abdomen, indicating that they have commenced feeding by April 10th or earlier.

In 1912, pupation had commenced at Gypsum, Ohio, by May 7, numerous pupae and larvae being found in the cells in the sapwood and a few in the outer bark. By the 18th of May, the pupation period was about closed. Only a few larvae could be found either in the field or in the laboratory breeding cages, and many of the pupae showed dark eye spots and mandibles. Other specimens, more advanced, showed these characteristics and also the dark chitinous plate of the thorax and darkening of the abdomen. On May 19, the first beetles emerged. Assuming these to have come from some of the earliest pupae noticed, about May 7th, we have 12 days or thereabouts as the pupal period. The mean temperature for the month of May was 60.7° F., or 1.5° F. above the mean. The temperature was 37° F., May 13th, and the weather for the entire period would be called cool. In July, the exact pupal period was established with two laboratory specimens which we will designate as A and B. The record, by dates, is as follows:

A

July	7,	Larva
"	8,	"
"	9,	Changed to pupa
"	10,	Pupa white
"	11,	" "
"	12,	" "
"	13,	Eyes showing dark
"	14,	Mandibles dark, also some other parts
"	15,	Thorax and abdomen dark
"	16,	Very dark
"	17,	Beetle emerged

Pupal period 8 days

B

July	7,	Larva
"	8,	Changed to pupa
"	9,	Pupa white
"	10,	" "
"	11,	" "
"	12,	Eyes slightly dark
"	13,	Eyes dark, also body parts
"	14,	Thorax and abdomen dark
"	15,	Beetle emerged

Pupal period 7 days

The following record gives the history of five pupae from larvae which were removed from their cells and kept in moist chambers:

July	8,	Larvae 5 in number, a, b, c, d, e
"	9,	Larvae 5 in number
"	10,	3 pupae, a, b, c
"	11,	5 pupae, a, b, c, d, e
"	12,	5 "
"	13,	5 "
"	14,	5 "
"	15,	5 "
"	16,	5 "
"	17,	b pupal period completed in 8 days; d, pupal period completed in 7 days
"	18,	e, pupal period completed in 8 days
"	19,	a and c, pupal period completed in 10 days

Much fuller breedings were made in the season of 1908, the pupal period being determined with several hundred specimens. The period for the spring brood derived from the winter larvae ranged from 8 to 18 days; for the summer brood from 7 to 12 days. In 1908, the first pupa was found April 20th, on peach. Several more were found during the next ten days and by the 30th were forming in the laboratory. May 20th appeared to be about the date for the maximum number of pupae belonging to the winter generation of larvae. June 1st was the latest date that a pupa of the winter generation was found. In 1909, pupae were found in the laboratory cages June 12th, and, as beetles belonging to this generation continued to emerge for some time later than this, it is presumed that the pupal period is in some years extended to about the middle of June. These laboratory specimens, in cages, in an unheated room indoors, were doubtless a little later in emerging than if they had been in the outdoor sunshine.

The earliest pupa of the summer generation was found July 6, 1908, and they were plentiful two or three weeks later. Pupae could be found from this time onward until late October, but so far as we have been able to determine, they all belong to the same generation. The statement* that sometimes larvae, pupae and adults may all be found in the same wood during the winter, is probably correct for localities in the southern part of the United States, but only larvae can be found in northern Ohio during the winter, and this observation corresponds with Dr. Forbes' findings for Illinois. The full grown larva burrows well out toward the outer bark before pupating and fills the outermost part of the burrow with a cap of frass or saw-dust. It then pupates with its head toward the cap, or in position to eat its way out through the bark when it attains the beetle stage.

FIRST GENERATION OF ADULTS

In 1912, the first adults were taken May 19; in 1908, May 20, and in 1909, the earliest record was of specimens appearing in a breeding cage, June 3. Mr. Wilson observes that at Longley, 50 miles south of Lakeside, "The beetles seem to reach the adult stage somewhat before those from Lakeside. Upon changing from pupae to beetles, the insects remain inactive for a day or so, merely moving their legs and antennae about. The eyes, mandibles and more heavily chitinized parts may become slightly tinged with brownish in the pupa stage, and these, with the antennae, are the first parts to show dark in the newly emerged beetle; next the thorax darkens,

*Circular 29, Bur. Ent., U. S. D. A.

then the tip of the abdomen, and gradually all parts assume brownish, later turning black. The beetles now eat their way out through the bark. Very few specimens with light-colored elytra are encountered outside the pupal cells, as they have nearly always become hardened and black before venturing from their burrows. About 10 a. m. they commence leaving their burrows and by 1 o'clock, the maximum rate of emergence is reached; a decline in the rate now commences and the exits for the day are practically over by 3:30 p. m., very few beetles ever appearing later than this. The beetles are much more sprightly in their movements over the bark than *Phloeotribus liminaris*. They are often seen running rapidly up and down the trunks and larger branches of infested trees, the males in quest of the females, and the females seeking for places to start their burrows. As soon as they emerge, the beetles immediately begin work on fresh wood. Both entrance and exit holes of the beetles are generally more numerous on the sides and under parts of the branches than on the upper surface, but they are not infrequent in the latter situation. The flight of these beetles is quite strong and they are doubtless capable of flying for a considerable distance, especially if aided by the wind. They readily take flight from breeding jars and from windows into the open. They are sometimes seen flying in the open and have been found on the inside of car windows, this indicating that they entered the cars while in flight through rather open spaces.

Food Habits: The female beetles obtain most of their food while boring through the bark to and from their brood chambers. Bark makes up the greater part of their diet, while the true wood forms only a small portion of the food. Beetles confined for a few days without food readily feed on fibers of moist bark.

Construction of the Brood Chamber: Very soon after issuing from the wood the females of the first generation begin the construction of their brood chambers. This work seems to be the most important of all their activities, since both feeding and reproduction are thereby accomplished. The males have no special mission except to attend the females. After a satisfactory place has been selected by the female, she starts gnawing with her powerful mandibles, during which process she clings tightly to the bark. While gnawing, her shear-like jaws may be seen rasping off fragments of bark while the ball-like head moves freely in the socket of the prothorax As the work advances, the beetles lift their bodies at all angles until they appear to stand upon their heads, for these entrance holes are made almost at right angles to the surface of the bark. Upon reaching the sapwoood, the burrows turn abruptly

upward and are continued with the inner half of the burrow in the sapwood, the outer-half in the bark. The rate of burrowing varies considerably; some beetles will gnaw a space the length of their body in 1½ hours, while it takes others 2 to 4 hours or more. The great majority of the entrance holes (about 75 percent) are made through the lenticels or bark pores. The remainder are started at abrasions or points of mchanical injury, at rough places, etc. The insects must find roughened or elevated places against which they can brace their feet to commence work, and also prefer such spots as the lenticel pores because of the corky texture of the cells which offer comparatively little resistance to excavation.

The holes in smooth bark are exit holes. These are generally arranged as an irregular and imperfect oval, each leading from the extremity of a larval gallery. An examination of Fig. 3 will make clear why the terminals of the galleries and, therefore, these exit holes form an imperfect oval.

Peach trees, cherry trees, and plum trees, badly attacked, are apt to exude gum in lage quantities through the entrance holes. Apple and pear, when attacked, do not gum so freely, generally, not at all. While the number of trees of the different varieties of fruits which we were able to observe may have been insufficient to warrant very definite or final conclusions, the indications are that plum, peach, cherry, apple and pear may be considered as preferred hosts in about the order named. Weakened trees in uncared-for orchards are most apt to be attacked, but healthy trees in the best cared-for orchards are not always wholly exempt. The Lesser Peach Borer, *Sesia pictipes*, the Peach Bark Beetle, *Phloeotribus liminaris*, as well as some other insects and diseases, may produce a very similar condition; therefore, a careful examination is necessary to determine if the Fruit Bark Beetle is the culprit. If small pits, cut through the lenticels into the sapwood are found beneath the gum this may be taken as presumptive evidence that either the Fruit Bark Beetle or the Peach Bark Beetle did the work, generally the preceding season. The Fruit Bark Beetle makes such burrows for the purpose of feeding, or possibly as the beginnings of brood chambers which are soon abandoned because of unfavorable environmental conditions. The Peach Bark Beetles make quite similar pits, but with enlarged cells in which to hibernate during the winter. Possibly the excessive quantity, or the adverse quality of the gum exuding, causes the females to abandon such burrows as not suitable for the rearing of their young. Damage begun in this way however, and continued for a few successive seasons may weaken the trees to such an extent that they may become exactly fitted for incubation purposes.

Plate III. Gumming from attack of Fruit Bark Beetle on trunk of old tree.

At the point where the entrance burrow meets the sapwood the chamber bends upward and extends approximately parallel to the axis of the trunk or branch in which it is made, and may reach a length of two inches or more, but the usual length lies between ½ inch and 1½ inches. The average length is very close to 1 inch. Where work is continuous, from 7 to 10 days seems to be about the time necessary to complete the chamber, but it is often, perhaps even generally the case, that the work is not continuous but intermittent, and that an indefinite, but longer period than the one just stated, is required.

Mating Habits: As soon as the female has lengthened her burrow enough to permit the entrance of her whole body, she ceases work long enough to accomplish mating. A male may be in waiting at the mouth of the burrow, in which case copulation occurs at once, or it may occur even before the female has excavated enough burrow to receive her body, or sometimes before she has commenced any burrow at all. Usually, however, the female ceases work and protrudes the end of her body from the entrance, and thus awaits the male. Copulation then takes place with the male outside the burrow and the female within it. In other cases mating is performed with both insects inside the burrow, with only the head of the male projecting. The only copulation that was timed required 20 minutes for its completion. The males can often be observed waiting for hours at a time at the entrance to the brood chambers. They seem to become restless at times and enter the burrow for a short distance and then back out. In a breeding jar, 19 males were counted on a single branch, all waiting at the same time at the entrances to the brood chambers in the bark. A number of these chambers were opened and found to contain female beetles, eggs, and very young larvae. Sometimes one male will drive another away from the entrance at which he is waiting. It seems probable that mating takes place several times during the construction of the brood chamber, and the length of the brood chamber and the number of eggs and larvae produced by the female may, perhaps, depend on the number of matings experienced in her lifetime.

Egg-laying and Galleries of the Larvae: Egg-laying or oviposition occurs soon after mating. The female commences the excavation of the brood chamber proper after copulating, the floor of it in the bast or sapwood, and the roof in the bark. Small niches or cells are made along the side walls, half in the bast and half in the bark; each is just large enough to receive an egg. After many attempts, Mr. J. L. King was fortunate enough to observe one female in the act of oviposition. The brood chamber had been opened by means of a sharp knife and a small flap of bark was lifted from the top of the brood chamber. A tiny egg-niche had been

made by the beetle before the burrow was opened. After some hesitation the beetle backed out of the burrow to the outside where she immediately turned about and backed into the brood chamber. Upon reaching the locality of the niche, she distended her abdomen and with it seemed to be feeling along the wall of the burrow as if hunting for the niche. After a few moments of exploring the niche was located. The tip of the abdomen was then held within the niche and a single tiny, translucent egg was deposited therein and left standing at right angles or endwise to the burrow. The beetle then crawled out of the burrow and entered again, head first, and upon reaching the niche she covered the egg with fine frass. The mouth-parts seemed to be used to cover the eggs; after covering them over the insect remained quietly within the burrow. There are two lines of eggs, one on each side of the burrow; the eggs are sometimes almost touching each other. The egg-lines extend backward into the burrow until the last eggs laid are practically out to the terminal corner of the burrow. It would be impossible for the female to place these newest eggs in position without backing into the burrow to do it. The frass-packing over the eggs practically makes an inner smooth tube in which the adult lives while the eggs and young are without. Each young larva commences the construction of a gallery outward from the brood chamber soon after it

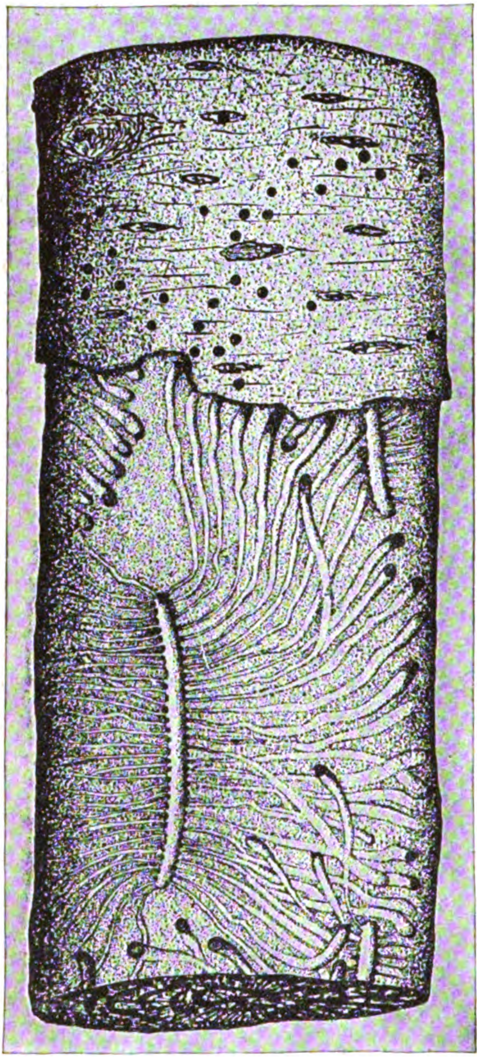


Fig. 3. Brood chamber and galleries of the Fruit Bark Beetle, *E. rugulosus*, natural size.

hatches, generally extending it at a right angle if near the middle of the chamber, and somewhat obliquely outward if originating near its end. The galleries diverge more and more from each other as they are enlarged in diameter, to accommodate the growing grubs. The general form of the completed burrow with its finished radiating galleries is shown in the accompanying drawing. (Fig. 3.) The flooring of the galleries, like that of the main chamber, lies in the sap-wood while the over-head roof is in the bark. These galleries are completely filled with a reddish-brown frass or excrement, derived from the bark. They vary in length from less than an inch to three or four inches or more in length, depending on the kind of wood used for incubation, and also on the crowding of the galleries, the meeting with obstructions or with old galleries of earlier generations, etc. The same area may be crossed and intercossed by the galleries of several different brood chambers. In cases of bad infestation the bark over the whole trunk and larger limbs may be so loosened that it falls away, or may be torn away by woodpeckers searching for the grubs, leaving the inner wood exposed and bare. Such an infestation means the speedy death of the tree, if it occurs in living wood. The areas generally chosen are dead or diseased patches of bark on otherwise healthy trees, or else the trunks and branches of weak and unhealthy trees. Egg-laying begins as soon as the burrow reaches the sapwood in case of those females which have mated, while some burrows from 3/8 to 1/2 inch long do not contain eggs, though females may be present. These females probably have not yet mated. The number of females appears to greatly exceed the number of males.

The period of incubation, so far as could be determined, is from 3 to 4 days. Of 7 eggs, laid in July and kept under observation, 3 hatched in 4 days and the remaining 4 in 3 days. The number of eggs deposited by one female in one brood chamber ranges from 20 to 163 or more. From counts made on 19 brood chambers, June 26, 1908, the minimum number was 30, and the maximum 112, the average 76. June 29, 1908, counts were made on 8 brood chambers and the minimum number of eggs found was 47, maximum 132, average 91. Counts taken on earlier dates gave smaller numbers, presumably because not all of the eggs had yet been laid. The earliest date of discovery of eggs in 1908 was June 7, but young larvae were found May 28 in 1912, indicating that egg-laying may commence about the 20th to the 25th of May in some seasons.

The entrance to old burrows is quite generally plugged with the body of the dead female. Whether she comes to the entrance to obtain fresh air when she is finally exhausted and life is flickering out, or whether she instinctively devotes her carcass as a protection against the entrance of parasites into the burrow can be only a matter of speculation.

FIRST GENERATION OF LARVAE

The newly hatched larvae are only about .55mm. long. Soon after the commencement of feeding a pinkish tinge overspreads the body due to the bark which they eat.

In 1908, the first larvae produced by the first brood of beetles were found June 13th. One larva was at this time 1-4 inch away from the burrow. Fourteen very young larvae were found to have hatched in the same burrow on this date. The larvae had become numerous by the end of June. They could be found from this time on until winter, because of some overlapping of the first and second broods.

In 1912, some larvae hatched May 28 and were full grown July 3, a period of 36 days being required to reach maturity. Another lot, hatching June 5, matured July 7, or within 30 days. When full grown, the larvae form pupal chambers at the ends of the larval burrows. These pupal cells are formed in the sound sap-wood just beneath the bark and are just deep enough to conceal the larvae. The entrance into these oval cells is plugged with sawdust or frass, having the inner portion of the plug very compact, the small particles being apparently gummed together by a secretion from the larva. After finishing the cell, the larva turns about and rests with its head toward the plug or cell-opening in which position it pupates, ready to bore through the bark to the outside as soon as it becomes adult.

Measurements in millimeters taken of a series of larval heads and mandibles indicate the probability of four stages or instars in the larval life as shown by the following table:

TABLE I. Showing measurements of the instars.

First instar			Second instar			Third instar			Fourth instar		
Length of head	Width of head	Width of mandible	Length of head	Width of head	Width of mandible	Length of head	Width of head	Width of mandible	Length of head	Width of head	Width of mandible
.26	.20	...	.36	.32	.12	.52	.48	.20	.72	.60	.28
.28	.22	.08	.32	.28	.12	.48	.40	.20	72	.60	.24
.24	.24	.1	.36	.28	.12	.56	.50	.20	76	.64	.28
.26	.22	.08	.36	.30	.12	.42	.44	.20	.62	.54	.22
.28	.26	.12	.32	.28	...	.48	.44	...	.60	.50	.22
.28	.26	...	.30	.26	...	.38	.32	...	.64	.60	.24
.28	.24	.08	.32	.28	.12	.40	.36	...	60	.52	.20
.28	.20	.08	.32	.28	.12	.48	.40	...	72	.64	.28
.24	.20	...	.36	.32	.12	.48	.44	.20	72	.64	.28
.26	.24	.12	.36	.32	.12	.56	.50	.22	.76	.72	.28
.28	.26	...	.32	.28	.12	.52	.50	.20	.60	56	.24
.26	.20	.08	.36	.32	...	.46	.36	.20	64	.56	.28
.28	.26	...	.36	.28	.12	.40	.36	...	.72	64	.28
.28	.24	...	.36	.32	.12	.44	.36	.20	72	64	.28
.28	.24	.08	.36	.32	.12	.44	.36	.20	76	66	.30
.28	.26	.08	.40	.36	.12	.44	.32	...	72	.64	.28
.28	.24	.08	...	...	...	.38	.32	...	72	.64	.28
.26	.24	...	...	...	...	...	...	...	...	...	...
.28	.26	.08	...	...	...	...	...	...	...	...	...
.24	.20	.08	...	...	...	...	...	...		...	...
Av. of 20 spec. .267mm.	Av. of 20 spec. .238mm	Av. of 13 spec. .087mm	Av. of 16 spec. .323mm	Av. of 16 spec. .30mm.	Av. of 13 spec. .12mm.	Av. of 17 spec. .461mm	Av. of 17 spec. .407mm	Av. of 10 spec. .20mm.	Av of 17 spec. 690mm	Av. of 17 spec. 608mm	Av. of 17 spec. 260mm

The individual measurements in nearly every case, as may be seen from an examination of the table, approximated some one of the averages closely enough to enable us to refer the specimen without much doubt to the corresponding instar as classified in this table.

MIDSUMMER BROOD OF PUPAE

As noted in the preceding paragraph, the pupal stage from the first generation of larvae is entered upon in early July or thereabouts. Since the pupal period for this season is generally from 7 to 10 days, or slightly more or less, the adults of the second brood begin to appear about the middle of July or a little earlier.

SECOND GENERATION OF ADULTS

We have already observed that there is some overlapping of the two generations of insects. The early beetles start about the middle of May, a few specimens coming earlier, and the brood is practically over by the middle of June, though a few females linger for nearly a month longer. When the males become aged and decrepit they drop to the ground and die, while the female dies, as a rule, resting in the mouth of her burrow. The second or summer brood of adults begins about the middle of July and they continue to issue until late August or early September. The accompanying curve (Plate IV), prepared by Mr. King, shows the rise and fall in numbers of the adults for the different dates of the season; the counts were made from specimens issuing from the laboratory breeding jars during the summer of 1912.

Beetles were found as late as Oct. 29, 1912, and were not infrequent in breeding cages until Oct. 19, 1908. Unhatched eggs could be found in the burrows until late in September, 1912, and larvae and pupae until late in October. These belated September eggs are presumably laid by stragglers of the second brood, though it is not impossible that they represented a partial third brood. Beetles emerging later than September have not been found laying eggs, and since no other stage than larvae can be found in northern Ohio during the winter or early spring, we are obliged to conclude that in all probability these late issuing beetles perish upon the coming of cold weather without reproducing.

HIBERNATING LARVAE

Most of the larvae must have been full fed at the outbreak of winter and made cells in the sapwood, then sealed themselves in by stopping the burrow connection with a cap of compact frass. They were thus in position to pupate and bore out through the bark as adults during the following May and June.

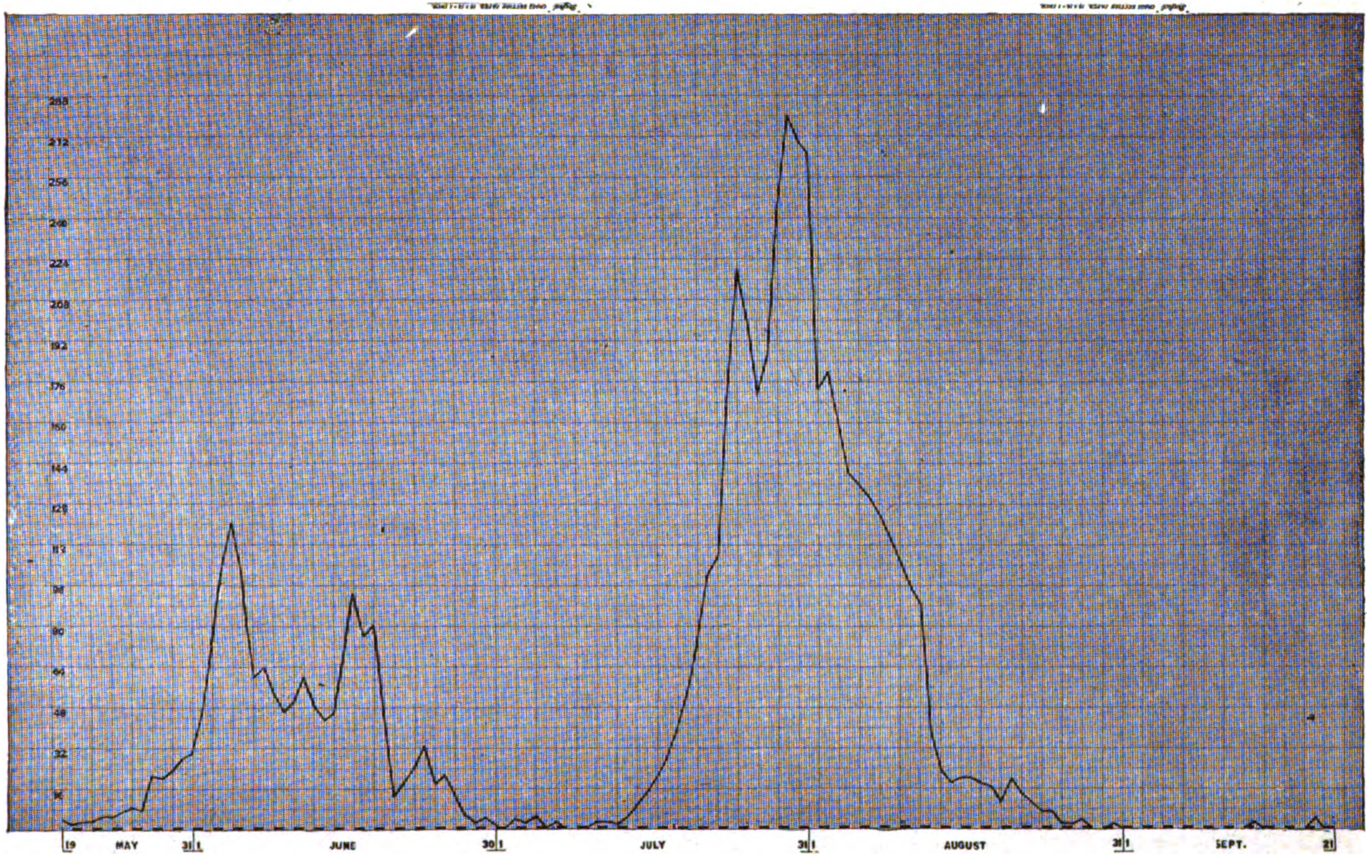


Plate IV. Curve showing rate of emergence of Fruit Bark Beetle, *E. rugulosus*, during summer of 1912. One small square upward represents one beetle emerging in the observation breeding cage and four squares longitudinally represent one day. The first brood is seen to be at its climax about the 5th or 6th of June and the second about the 29th or 30th of July.

Some of the larvae are found under the bark, and these probably feed until they become torpid and, as recorded at the beginning of the life cycle, they resume feeding in the spring. The record of the life cycle is herewith completed and connects back with the paragraph on "Hibernating Larvae," page 11.

CHARACTER OF INJURY

Reference has already been made in the "Introduction" and also in the paragraph on "Brood Chambers" to the general and also to some of the particular phases of injury caused by this bark beetle. Generally speaking, the beetles confine their attack during the early part of the summer, from May until late in June, to winter-killed and dying trees. The winter of 1911-12 was very severe throughout Ohio and many peach trees in the Lake District were weakened or killed. Many trees came into bloom and leaf, then withered and died. Trees in low, undrained orchards specially suffered, these, and also many that were weakened by the Peach Tree Borer, *Sanninoidea exitiosa*, dying. These dead and nearly dead trees formed the chief breeding places for the beetles. Attacks on such trees cause little or no gum flow. If sufficient life is still in the tree to cause an outflow of gum, very few of the brood chambers will be found to contain larvae. While larvae may sometimes be found in large numbers on living trees, close examination will show that they are located in a deadened or nearly dead area, and that few or none can be found where there is real live wood with sap coursing through it. However, if no damage at all were ever in any way inflicted upon living trees, the insect could not be classed as specially harmful. Vigorous, healthy trees are attacked by the adult beetles in late summer and fall, causing a copious gum flow and a gradual weakening. Entrance into the bark is nearly always made through the lenticels or through rough places and abrasions. From each hole exudes a quantity of gum which gradually accumulates outside. Where the beetles are exceptionally numerous, because of favorable breeding conditions in the neighborhood, and the supply of weakened trees has become exhausted, they may concentrate upon healthy trees to such an extent that these gradually become weak and furnish within one or two seasons a perfect condition for incubation. We have sometimes had reports of vigorous, healthy trees being killed outright in a few weeks by such onslaughts, but thus far have not been able to confirm the reports. However, we strongly suspect they are sometimes correct.

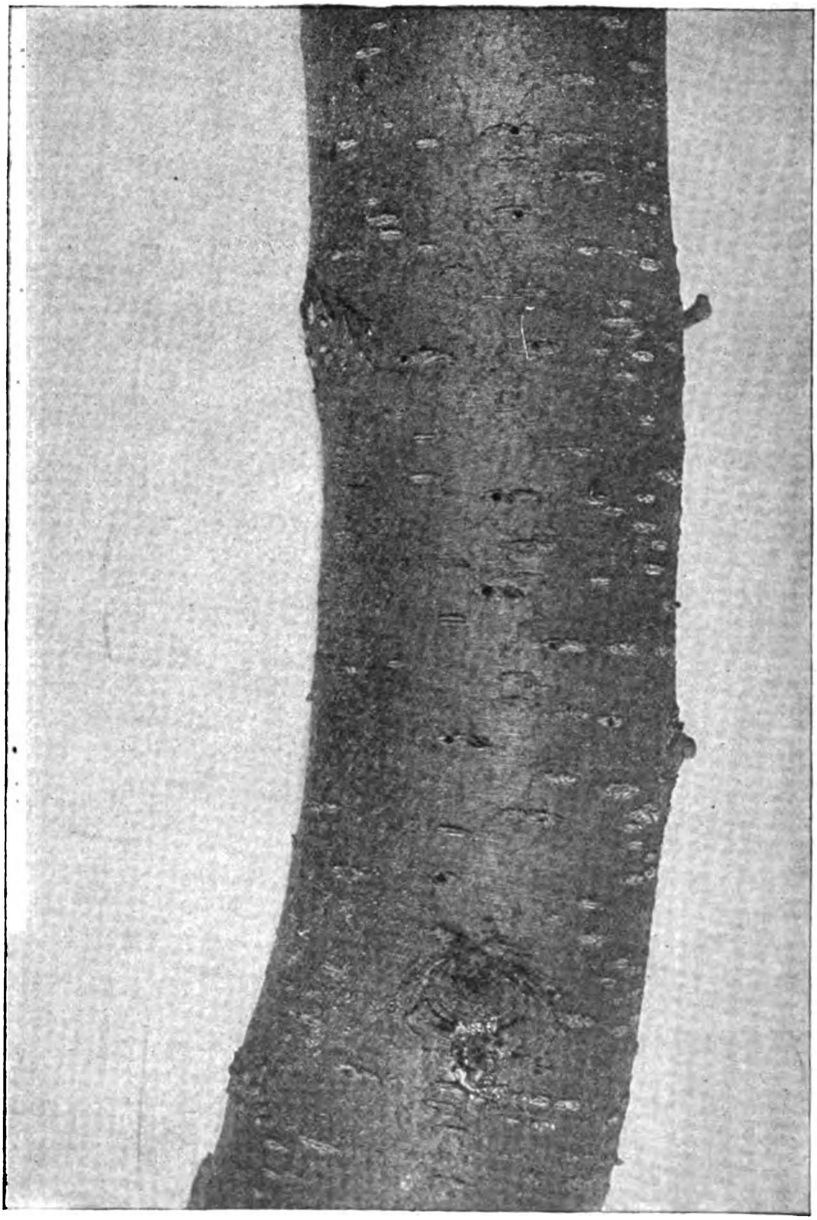


Plate V. Entrance holes of Fruit Bark Beetle, *E. rugulosus*, through lenticels and roughened places.

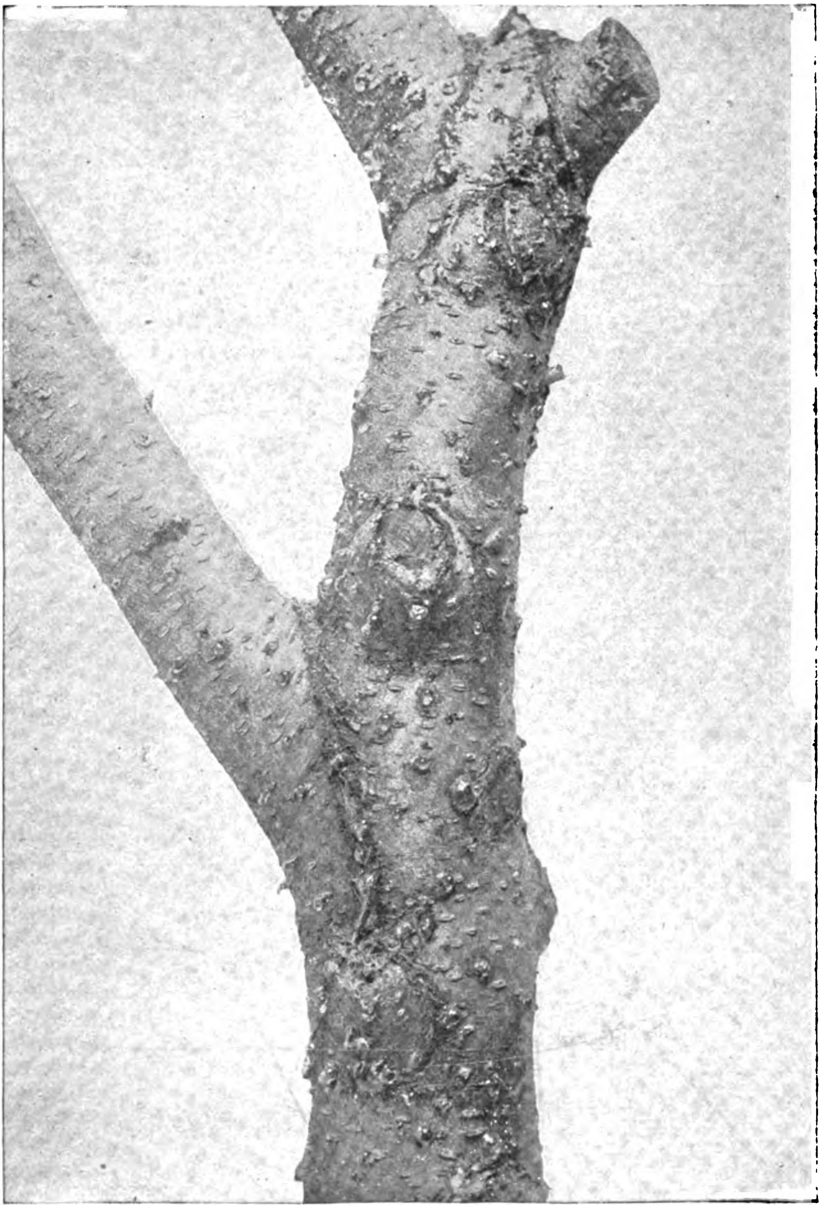


Plate VI. Gum exuding from feeding punctures of *E. rugulosus*.

In 1912, these attacks on living trees were first noted Aug. 14. The beetles were making these feeding chambers chiefly on branches two or three years old, and into the new twigs. On the twigs the beetles were boring shot holes in the crotches of the leaves and of the winter buds or in leaf scars. A few beetles could be found embedded in the exuded gum-drops like fossil insects in amber. Later in August more trees were found with the beetles at work on the trunks and larger limbs. Here, again, according to the seemingly invariable rule previously stated, the entrance holes were made through the lenticels and roughened spots on the bark. From such trees more than a gallon, in some cases two or three gallons, of gum would be adhering to the bark or collected into masses near the ground. Sometimes both *E. rugulosus* and *P. liminaris* are found working at the same time on the same trees.

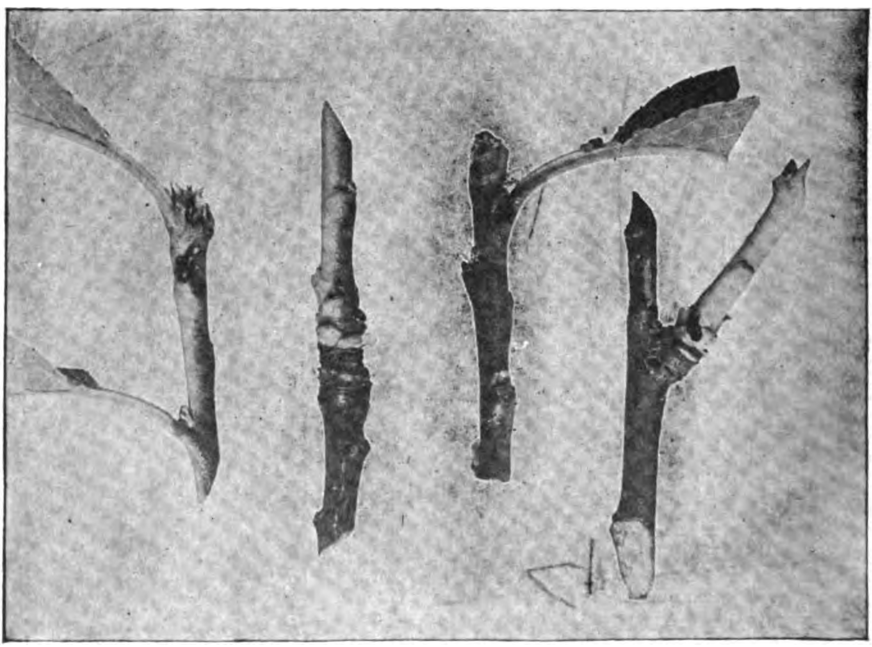


Fig. 4. Note beetles entering at bases of buds and in crotches of the leaves.

Under date of July 18, 1908, Mr. Wilson noted that all the dead and dying limbs of peach, plum and cherry were loaded with larvae, pupae, and beetles about to emerge. It was impossible to find wood with which to supply the breeding cages without cutting branches from perfectly healthy trees. One tree that was apparently in a healthy condition the preceding fall was attacked and then deserted

as the gum quickened its flow; it poured out through the holes as if through a strainer. Later, the same season, the beetles apparently made a second attack and completed the death of this tree. It is upon this instance as well as upon reports from correspondents, that we base our expressed opinion that perfectly healthy trees may sometimes be killed in a few weeks and before any brood chambers are constructed. July 30, 1909, Mr. L. L. Scott noted that "some of. the weaker trees showed some beetles attacking them, notably on those parts of the trees which were partly dead or dying. On more healthy parts of the same trees the beetles had made their attacks, but in most instances, had been repulsed by the copious exudations of sap. Such attacks usually extend well into the tops and smaller limbs of the trees and, in several instances, the loss of sap was great enough to so weaken the trees that the egg burrows were completed without the beetles being driven out by the flow of sap. In all cases, only the weaker trees are attacked; those which are healthy and show a strong and luxuriant growth with smooth bark, are in no case to be found infested."

Fig. 5. Cage for confining beetles to trunk of a healthy tree.

Fig. 6. Interior of cage about healthy peach tree a few weeks after arranging. Note the dead wood piled at base and gumming of the trunk.

In order to test the foregoing question experimentally, Mr. King was instructed to construct a suitable cheesecloth cage about a vigorous, healthy tree and pile inside it large quantities of infested

wood so that the beetles, upon emerging, would be obliged to attack it in excessive numbers, both to obtain food and to oviposit, if oviposition were possible under such circumstances. Accordingly, July 13, 1913, a cheesecloth box-cage was constructed about the trunk and over some of the lower branches of a vigorous, healthy Elberta peach tree, the lower branches being cut square across at a uniform level to permit their being enclosed. The trunk passed out through the top-center of the cage and carried the larger part of the untrimmed top above the cage under ordinary normal conditions. Then at the base of the tree within the cage was piled a large quantity of dead wood containing larvae of *E. rugulosus*. The tree used was 8 or 9 years of age, about 10 feet high and had approximately 12 feet spread of top. It was in vigorous health. The cage was about 5 feet high, 3⅓ feet wide and 4½ feet in depth from front to back. The following notes record the result of the test:

"Aug. 7. Beetles emerging and attacking tree, always starting at pores in the bark. Weather very dry. Little bleeding at punctures.

Aug. 19. Beetles have attacked tree badly, causing a copious flow of gum from most all the lenticels, though the upper part of the tree shows no difference in color, nor any symptoms of a weakened condition.

Sept. 8. Though the tree has been badly bled, it no doubt will survive. The leaves on the small twigs in the enclosure have all been killed by beetles boring in at the base of the petiole, or behind the winter bud. No larvae were found within the tree. A few of the beetles oviposited in the dead wood which was left in the cage.

All the fruit ripened normally on the tree."

Though the result in this experiment was negative, we are not convinced that it is impossible for the beetles to kill healthy trees in a brief period. The fact that all small limbs and twigs within the cage died outright suggests that if the entire tree had been enclosed so that all the twigs and smaller limbs could have been attacked the whole top might have quickly succumbed. The purpose in enclosing only part of the tree and leaving most of the top outside the cage was to avoid complicating the questions of injury by shade and impeded circulation of the air with bark beetle damage.

The following quotations from other investigators are of interest in this connection:

Professor S. A. Forbes in his 15-17 Illinois Report (1885-90), pp. 1-12, says: "Two vigorous peach trees which showed the characteristic perforations very thickly placed, did not have the bark undermined, but these trees had bled very freely, the gum having run down the trunks to the ground in considerable quantities."

Again, in conclusion we note from Dr. Forbes: "Certainly, however, in Illinois, so far as one may judge from observations already made, plum and cherry trees which would pass as healthy, even those still young and thrifty, sometimes suffer serious injury. On the other hand, we have had occasional instances of a vigorous attack made on the trunk and branches of the peach which was apparently repelled by the great effusion of sap, so that no injury had resulted, except such as would follow from this profuse bleeding."

Mr. V. H. Lowe notes serious injury caused by *E. rugulosus* in 1899 in Bulletin 180, N. Y. Agricultural Experiment Station (Geneva, N. Y.), 1900. On page 122, Mr. Lowe notes injury to healthy cherry trees by the formation of round holes at the spur of the leaves. He states that one-fourth to about three-fourths of the leaves were dead, and that a fourth survey in the vicinity of Geneva, and in Monroe and Niagara counties, showed that this species had caused extensive injury during the season, then past, to healthy vigorous trees.

Dr. John B. Smith, in Bulletin 235, N. J. Experiment Station, p. 36, (1911), states the following concerning *E. rugulosus*: "It is an imported species and attacks almost all of our common orchard trees, boring into the bark to the bast and there making galleries in which the larvae develop. Perfectly healthy, vigorous trees are almost never attacked, and if entered by the beetle, the larvae do not find it possible to develop; but anything that serves to weaken or drain a tree, or make it temporarily less resistant, may serve to give these insects a foothold."

DISEASES RESEMBLING WORK OF FRUIT BARK BEETLE

We have already referred to the similarity between the symptoms of injury made by *E. rugulosus* and that inflicted by *Phloeotribus liminaris*; likewise, to the gumming caused by the presence of the peach boring moths, *Sanninoidea exitiosa* and *Sesia pictipes*; but, gumming may also be caused by the presence of bacterial diseases. One of these is called gummosis because of the excessive exudations of gum coming from infected pockets on the trunk. This disease is especially apt to accompany a hide-bound condition of the tree, following a severe infestation with San Jose scale. All of these manifestations of injury may be mistakenly attributed to the presence of *E. rugulosus*. The presence of shot-like holes in the bark, and of larvae beneath, and the form and position of the burrows will enable one to correctly separate an attack of the Fruit Bark Beetle from these other maladies.

HOST PLANTS

At Gypsum, Mr. King found the following plants harboring *E. rugulosus:* Cultivated plants; apple, pear, cherry and peach. Uncultivated plants; black cherry (*Prunus serotina*) and wild plum (*Prunus americana*). In addition to this list, Mr. Wilson recorded it at Lakeside on quince and plum among cultivated plants. From the quince a female beetle was taken, and in her burrow 23 eggs were found. European writers had previously recorded most of these hosts, all of the cultivated ones, and in addition thereto the apricot. Mr. F. H. Chittenden adds the nectarine in Cir. 29, Div. of Ent. U. S. D. A. Dobner records mountain ash as an European host, as does Eichoff hawthorn and elm.

PARASITES AND NATURAL ENEMIES

A hymenopterous parasite, *Chiropachys colon*, was quite common about the burrows of *E. rugulosus* in July, 1908. Tiny nematode worms were found by Mr. King as parasites in the bodies of the beetles. In form and color these were like the vinegar eel. *Anguillula aceti*, but smaller, ranging from .28-.44 mm. in length.

The various woodpeckers are voracious feeders upon the larvae, and badly infested trees are sometimes seen in the spring of the year with the bark practically all stripped away from the trunks and larger limbs, and hanging in loosened sheets and shreds over the bare wood—the result of winter work by these useful birds.

In Europe, two hymenopterous parasites, *Blacus fuscipes* and *Pteromalus bimaculatus* are effective agents in keeping the borer in check and deserve introduction into this country. The most common parasite which we already have, *Chiropachys colon*, is sometimes very prolific and effective. Dr. Chittenden notes that in one case, coming under observation at Washington, 92 parasites were reared from infested twigs against 72 beetles that escaped being parasitized. All but two of the parasites were *C. colon*. About one-half dozen other parasites have been reared from the larvae and a number of predaceous beetles have been recorded as probable enemies.* Up to the present time, none of these natural enemies, except the woodpeckers, have been noted as specially effective in Ohio, though *C. colon* was quite common in 1908, and it may have played a more important part than we discovered in reducing the beetle to comparatively unimportant numbers.

*Circular 29, Div. Ent., U. S. D. A., p. 6.

THE PEACH BARK BEETLE

Phloeotribus liminaris Harris.

HISTORY

This insect was early recognized as a peach pest, Miss H. H. Morris recording the belief in 1849 that it was the cause of peach yellows. The large number of beetles found on trees suffering with this malady constituted the basis of her opinion. Harris in his book on "Insects Injurious to Vegetation," published in 1852, writes as follows: "There is another small bark beetle, the *Tomicus liminaris* of my catalogue, which has been found in great numbers by Miss Morris under the bark of peach trees affected with the disease called "yellows" and, hence, supposed by her to be connected with this malady. I have found it under the bark of a diseased elm, but having nothing more to offer from my own observations concerning its history, except that it completes its transformation in August and September. It is of dark-brown color, the thorax all punctured, and the wing covers are marked with deeply punctured furrows and are beset with short hairs. It does not average one-tenth of an inch in length."

The elm beetle which Mr. Harris supposed to be *Phloeotribus liminaris* has since been proved to have been a different species. Occasional references to the Peach Bark Beetle are scattered through entomological literature between 1852 and 1902, some of these clearly indicating that the serious nature of the pest was recognized by more than one observer. Thus, Prof. C. V. Riley, writing in the Rural New Yorker Dec. 24, 1881, speaks of the "Beetle which is doing such injury to peach trees," further referring to it as an "Old acquaintance long known to injuriously affect peach trees." W. L. Deveraux, in the same issue of the same paper, says: "This beetle is a much more serious pest than any of the other injurious insects attacking and burrowing in the trunk and branches of the peach tree." In the Rural New Yorker of May 19, 1883, W. L. Deveraux writes: "This pest which works so much damage to peach trees," etc. Prof. J. A. Lintner writes as follows in Country Gentleman, July 9, 1885: "The injuries from *P. liminaris* seem to be rapidly increasing. They have been quite destructive for two or three years past at Bethlehem Center in the vicinity of Albany, and what is believed to be the same insect has killed many hundreds of young peach trees at Keuka, Steuben Co., N. Y., the last year." The same entomologist says in the Ninth Report of the State Entomologist of N. Y., in 1892: "If this little beetle once takes possession of a tree, unless it should be found that it can be effectually killed by kerosene as suggested (applied with an atomizer), the fate

of the tree is sealed and it cannot long survive." Prof. M. V. Slingerland in the Rural New Yorker, Oct. 21, 1893, says: "Where the beetles occur in large numbers the tree soon shows the effect of their attack. They are present in alarming numbers in many orchards in N. Y. State and Canada." Dr. James Fletcher in the Twenty-sixth Report of the Entomological Society of Ontario, 1895, speaks of the "Peach Bark Borer (*Phloeotribus liminaris*) which has for some years done so much harm in the peach orchards of the Niagara peninsula." In the transactions of the Royal Society of Canada, Vol. V, Sec. IV, 1899, the same author observes: "One of the most serious enemies of the peach grower in the Niagara peninsula, although frequently overlooked, is this minute Scolytid, which, although one-twelfth of an inch in length, by reason of its attacks and those of its larvae, causes such an enormously disproportionate outflow of gum from the trees that they are soon weakened and killed." In 1909, Mr. H. F. Wilson published as Part IX, of Bulletin No. 68, Bureau of Entomology, U. S. D. A., a comparatively full account of its life history and economy, based upon his observations in the Lake region of northern Ohio. It has been recorded from Michigan and probably ranges farther west than is known. It is at present recorded from New York, Pennsylvania, New Jersey, Ohio, Maryland, Virginia, West Virginia, Michigan, Niagara district of Ontario province, Canada, North Carolina and New Hampshire. Mr. Chas. Dury, of Cincinnati, gives Tyngsboro, Mass., as an additional locality, and has a pair collected by himself at Browsville, Texas, which he "believes to be this species or very close to it." While Entomologist of the Ohio Station, Prof. F. M. Webster, under date of Dec. 31, 1901, makes the following statement in a letter to Mr. Geo. E. Fisher, Freeman, Canada, who had sent specimens of the beetles and samples of their work for identification: "I have only found it, (*Phloeotribus liminaris*), in Arkansas and once or twice in Ohio." Prof. J. M. Swaine says the species continues to be common and injurious in southern Ontario, and is also very common in southern Quebec on wild cherry, but he has never found it in Quebec orchards.

Its most serious injuries have been wrought in Ohio, New York and Ontario. Its devastations have been practically confined to peach, cherry and wild cherry.

OCCURRENCE IN OHIO

The Peach Bark Beetle is a native American insect and before the introduction into this country from Europe of the cultivated varieties of cherries and of peaches, it probably confined its attention to our wild choke and bird cherries, or their near relatives, such as

wild plums. It may have always existed in Ohio and adjoining states, such as West Virginia, where it is known to be widely and quite evenly distributed, but only in recent years has it attracted special attention in our state as a fruit pest. The concentration of peach orchards along the Lake Shore and the unhealthy conditions which have developed in many of these from the work of San Jose scale, other peach pests, and from the neglect of their owners, have produced an environment very favorable to the excessive multiplication of this species. It has been present in injurious numbers over a territory of something like 100 square miles, or most of the Marblehead peninsula and the adjacent islands for the past seven years, and was likely responsible for much of the damage in the same region, which, in the years immediately preceding, was credited to the Fruit Bark Beetle, *Eccoptogaster rugulosus*. Since both insects were generally at work in the same orchards, and frequently upon the same trees, this confusion was very natural and only an expert examination would be likely to discover the presence of both insects. In July, 1907, Mr. W. H. Wright, of Lakeside, called the attention of the writer to his orchard which was suffering greatly from an attack of bark beetles. At the time of the examination, only *Eccoptogaster rugulosus* was noticed, this being the proper time for the culmination of the summer brood of this species, and it was not until Mr. Wilson took up a minute investigation of the insects at work that the presence of *Phloeotribus liminaris* was discovered.

Wherever the orchard owners, generally, have whitewashed or otherwise treated their orchards, and have promptly burned all trimmings and dead wood, there has been considerable abatement of injury. Since these practices became quite general, at least for two or three seasons, the benefits have been quite discernible throughout the whole of the infested district.

Mr. Dury says of its distribution around Cincinnati: "I have never found it very abundant here and I have been collecting in southwestern Ohio for over 40 years." Mr. Wilson, in the publication previously referred to,* speaks of its having been captured at Youngtown, the statement probably being founded on records in the U. S. Bureau of Entomology. A specimen in the collection of the Ohio State University is labeled "Columbus, O., April 20, 1896." We have no knowledge of this species ever having done serious injury in any other locality in Ohio than in the beforementioned Lake district.

*Bulletin No. 68, Part IX, Bureau of Entomology, U. S. D. A.

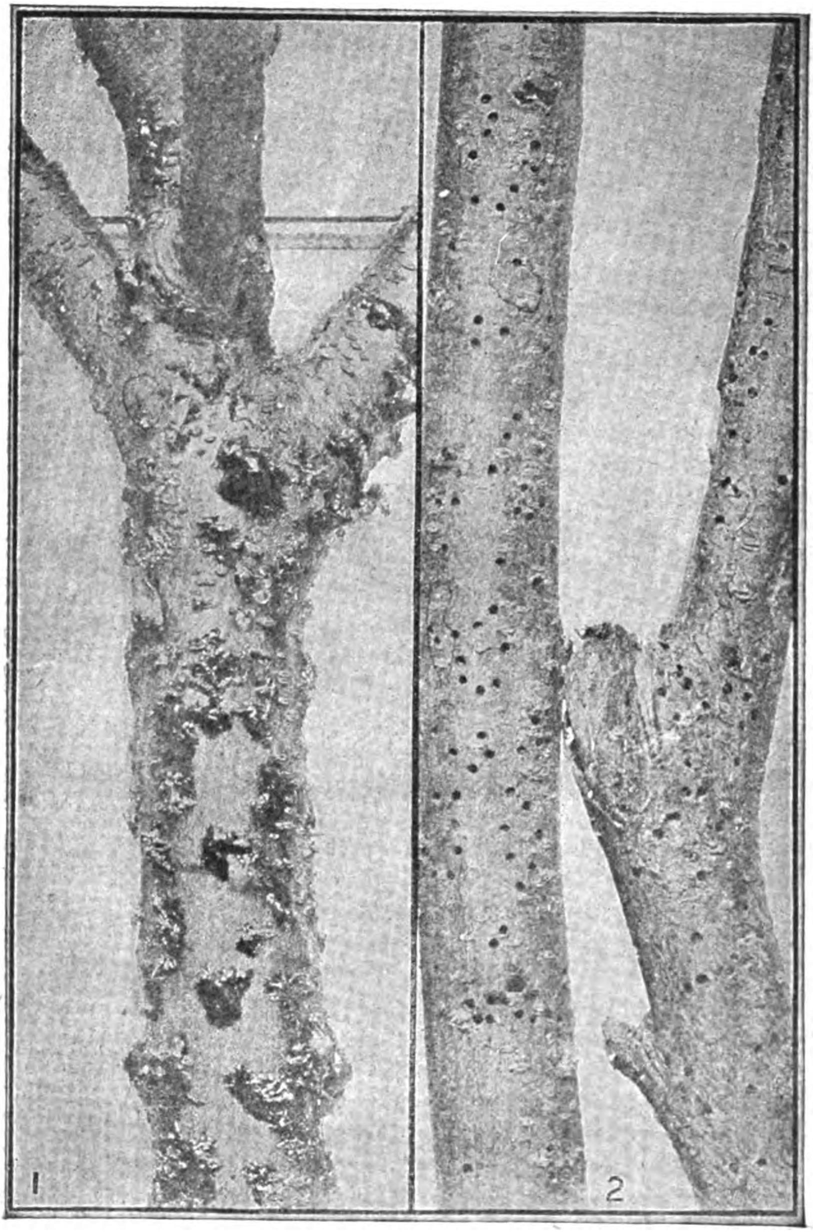


Plate VII. Exit holes and gumming caused by the Peach Bark Beetle, *Phloeotribus liminaris*. Photo. by H. F. Wilson (Bul. Bur. Ent. U. S. D. A. No. 68, Part IX.)

SYMPTOMS OF INJURY

The general symptoms of injury by this species are so like those which accompany the presence of the Fruit Bark Beetle, *Eccoptogaster rugulosus*, that a casual examination of its work is almost certain to lead the observer to attribute the damage to the more common insect. The trees gum copiously, the bark of the trunks and larger limbs being perforated with minute holes resembling the punctures made by fine bird shot, and the inner bark and cambium wood are channeled through in various directions and destroyed. As much as three or four gallons of sap may exude from a single tree of ordinary size in one season. A wild cherry tree, 75 feet or more tall and about 14 inches in diameter, on the Marblehead peninsula, was apparently killed by these beetles alone. If it was assisted by the Fruit Bark Beetle, the work of the latter was undiscoverable. All the bark from this very large tree was completely devoured by the insects. Trees that generally pass without question as healthy are attacked by the beetles for the purpose of feeding, but such trees are not selected for incubation. As winter approaches, the beetles burrow into the bark of healthy trees and construct cells in which to hibernate; a certain amount of gum will exude from each of these holes the next season and, in the spring, when the insects emerge from their winter chambers, they burrow from a quarter to one-half inch in the bark of the same or of nearby healthy trees, and the exudation from these added to that coming from the hibernation burrows, weakens the tree to a considerable extent; and when the attacks are renewed, as is apt to be the case later in the season, and also from year to year, the trees quite soon, almost certainly in three or four years, reach that sickly condition which best fits them to be rearing grounds for the young larvae. Egg burrows and larval tunnels are then made and the larvae quickly complete the destruction commenced by the adults.

DESCRIPTION

Egg: Milky white when first deposited, elliptical in shape, opaque and measuring on the average .44 to .47 mm. or about 1-50 of an inch long and a little more than two-thirds as much through the middle diameter (.36 to .39 mm. as an average,—approximately 1-75 inch). The egg shells are sufficiently tough to easily admit of the removal of the eggs from the burrows without breaking them. They can be more certainly preserved and handled by being boiled for a few moments in water.

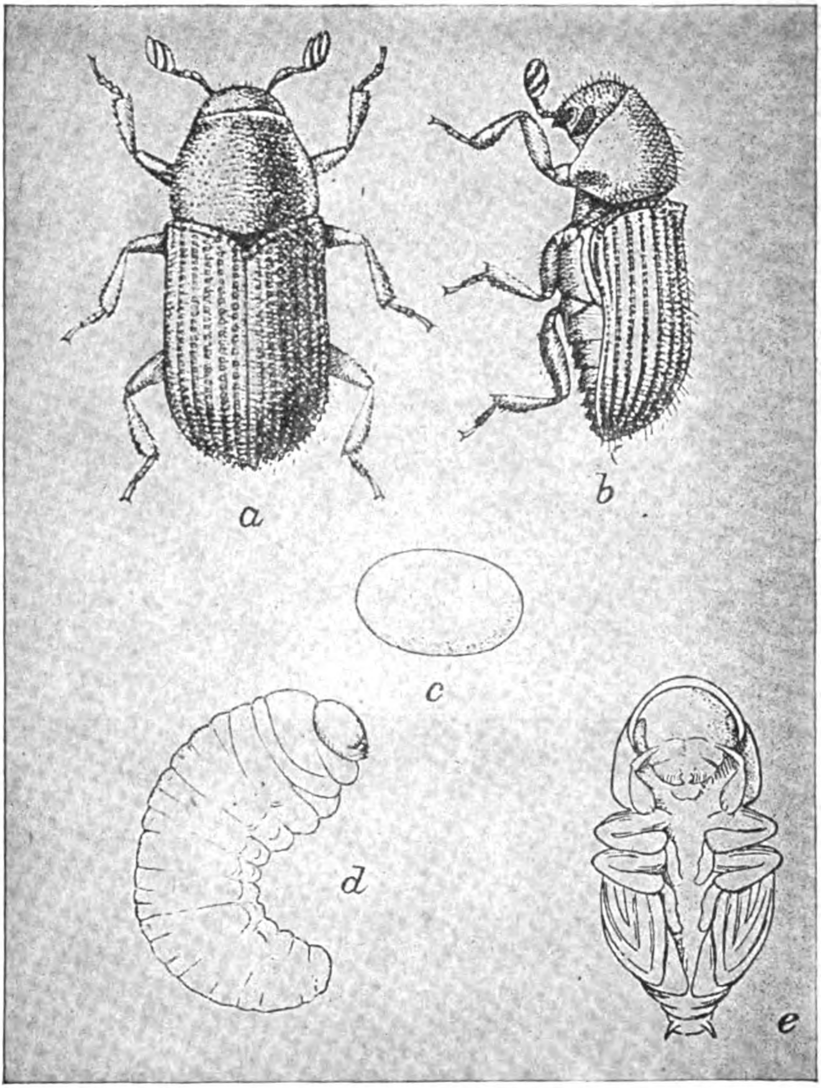


Plate VIII. Much enlarged figures of stages of Peach Bark Beetle, *Phloeotribus liminaris*: a and b, adult beetle; c, egg; d, larva; e, pupa. After Bur. Ent. U. S. D. A., Bul. No. 68, Part IX.

Larva: The new-born larva is a little longer than the egg and slightly more slender. The color is white but soon becomes pinkish, owing to the contents of the digestive tract. When full grown, about 25 to 30 days after hatching, they void their excrement, become clear white and pupate. They are then from 2.75mm. to 3mm. long. The head is covered over with fine, yellowish hairs at all times, these being most abundant about the mouth. Therefore, the head is always yellowish in color; the jaws or mandibles are brownish with dark tips. The body is curved, tapers somewhat toward the rounded posterior end and is quite wrinkled. Small groups of bristles occupy the places where legs are commonly found in this order. Many minute, short spines are distributed all over the body.

Pupa: Length 2.5 to 2.66 mm.; width 1.08 to 1.11 mm. Body white, showing a suggestion of yellow on the sides of the abdomen. Eyes, reddish brown; interior mouth parts, faintly brownish. Two whitish, brown-tipped horns terminate the abdomen, one on each side.

Adult: Average length 0.0885 inch or 2.25 to 2.5mm. and average width about .03 inch or .75 mm. The body is elongate, strongly punctured and has yellowish hairs arising from the punctures. The color varies from light brown to almost black. The underside of the abdomen is gradually concave and in strong contrast to the angle on the abdomen of *Eccoptogaster rugulosus*, where the posterior segments are reflexed suddenly backward and upward from the more forward ones. The wing covers are deeply margined, sides parallel, surface with regular grooves in which are ranged numerous circular pits, the elevated parts with yellowish hairs arising from faint punctures.

The following technical description by Mr. Wilson is appended for the use of Entomologists:*

"Average length, 2.25 mm., average width, 0.75 mm. Body elongate, subcylindrical, strongly punctured and with yellowish bristles arising from the punctures; color varying from light brown to almost black. Head globular, nearly vertical in front, anterior part fringed; eyes narrowly oblong, closely joined to the scape and extending about half their length below it; mandibles short and broad, distal part curved and strongly acute; mouth parts partly inclosed, gular suture distinct; funiculus of antennae five-jointed; club compressed, composed of 3 triangular segments; first joint longer than wide, globular; scape circular, clavate. Thorax almost cylindrical, strongly angled at caudal end. First and second coxae widely separated, globular; femur stout, outer edge serrated; tibia, third joint bilobed, fourth indistinct, fifth as long as first and second together, tarsal claws simple. Ventral side of abdomen and posterior edge of last segment strongly concave; elytra anteriorly rounded and deeply margined, sides parallel, surface with regular striae which contain circular, regularly placed depressions, elevated parts with yellowish bristles arising from faint punctures."

*Bulletin 68, Part 9, Bureau of Entomology, U. S. D. A.

LIFE HISTORY AND HABITS

In northern Ohio the hibernating beetles commence cutting their way out from their winter cells with the first warm days of spring, sometimes in late March, but it is generally later than this before the majority of them become active. About the middle of April or a little later, under average conditions, they may be seen issuing in numbers from their burrows and crawling about over the trees. In 1908, activity was observed April 8 in orchards near Lakeside. A beetle, here and there, could be found on the bark, and openings had been quite generally made from the pupal cells to the outside. The beetles would move about somewhat sluggishly when cut out from their burrows, notwithstanding the chilly temperature. April 16, 1912, they were working in peach and cherry at Gypsum, the brownish frass at the mouths of their burrows indicating their whereabouts, and also that they had been feeding for a few days. The interval between their resumption of activity and their appearance outside their burrows, usually of three or four days to a week or longer, is spent in feeding.

Both dead and living wood is used for hibernating cells, and when they leave their winter shelters, they go to either dead or living trees, to wood piles, to brush heaps, or to any wood in which they can feed and rear their young. Migration from tree to tree is usually accomplished in the afternoon, but little flight being indulged in during the morning hours and practically none at night. During the daylight hours, the females seek suitable situations for starting burrows, while the males seek the burrows of females not yet appropriated by males. Flight and movements over the tree cease when nightfall is well settled, though flight seems to be most active just at the twilight hour. Migrational activity apparently commences about the middle of the afternoon.

The burrows of this insect are characteristic and readily distinguishable from those of *Eccoptogaster rugulosus* and other common shot-hole or pin-hole beetles. The entrance to the burrow is partially closed by a gummy exudate, mixed with bits of bark-dust and frass, the mass being bound together with a fine silken thread which is manufactured by both sexes. This mass, partially covering and extending somewhat into the burrow, is not found at the entrance to the burrows of *E. rugulosus*. The female commences burrowing into the bark, nearly always entering at a lenticel, and if the sap in the tree proves scanty, she constructs the brood chamber just between the sapwood and the bark; if, however, the sap is abundant, the galleries are confined to the bark, though sometimes impinging on the sapwood. The main chamber of the burrow may

be anywhere from 1 inch to 2.625 inches long, the average length being about 2.06 inches. The diameter of the main burrow varies between 1-8 inch or less to 3-16 of an inch or thereabouts. It is nearly always formed transversely across the trunk or limb, but is occasionally inclined at an angle of 45 degrees or less to the axis of trunk or branch. Since the main burrows of *E. rugulosus* are more often than not vertical, or nearly so, there need not be much doubt as to which species formed any particular burrow. A fork is formed well toward the inner end of the burrow, commencing at the point where the burrow first touches the sapwood. When the point is struck, the female forms a little niche at an angle to the part already excavated, and she then begins excavating in the opposite direction, thus making another and approximately equal angle with the main burrow. While this opposite extension is being made, the male copulates with the female at the fork. When in copula, the female occupies one arm of the fork, head inward, the point of her abdomen just at the fork, while the male operates from the other arm. At other times, the male may be found almost anywhere in the burrow, between his special niche and the burrow's mouth. Only a single pair are to be found in a burrow. Copulation occurs an indefinite number of times, and has been observed on several

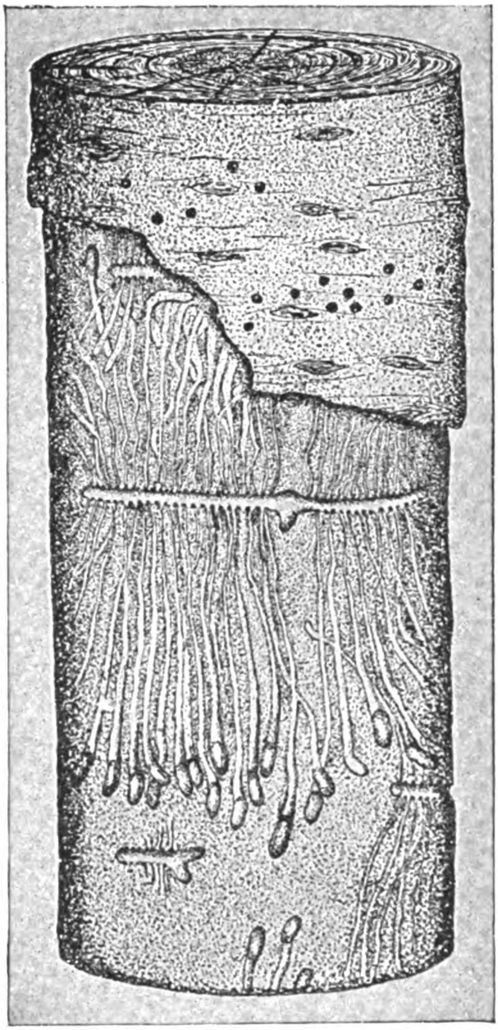


Fig. 7. Brood chamber and galleries of *P. liminaris*.

occasions to continue for 15 minutes and longer after the burrow was cut open. The two forks of the chamber may differ considerably in length. The time consumed in constructing the brood chamber may vary from 10 days to 3 weeks and possibly, under unusual conditions, the period has yet wider limits in both directions. After entering their brood chamber, the male and female of each pair seem to remain there until they die; they may sometimes be found in their burrows, feeble and sluggish, after some of their offspring have reached the beetle stage.

Along the sides of her burrow, the female excavates little niches which may be very close together or considerably separated. These cells are for the reception of eggs, one egg being deposited in each cavity. The eggs are not ranged in straight lines along the sides of the chamber, but may zigzag a good deal. The distance between the eggs is somewhat variable; two may be touching, while others are separated by an interval. However, since the egg-cells are generally located where the bark and the sapwood meet, there will always be two plainly discernible, though not very straight, egg-lines in each burrow. This arrangement holds good in those cases where the burrow is not made next to the sapwood, this sometimes occurring where the bark is very thick; in such a case the burrow is formed in the bark at a depth of about one-fourth inch. As soon as the female has excavated a cell, she backs out of the burrow to the fork, when she reverses her position, and backs into the burrow until she reaches the cell just made, in which she deposits an egg. She then crawls forward to the fork, again turns round and creeps into the brood arm, head foremost. She then proceeds to cover the egg, which stands on end in the cell, with a sawdust-like frass. These sawdust caps over the cells are confluent and form a tubular lining to the burrow, smooth within, and the eggs outside of it. Each egg-cell is filled with an egg as soon as completed, and a new one is excavated as soon as the burrow is extended far enough to make room for it. Deposition of eggs commences as soon as the female has been fertilized, which is generally within a week or so after activity has begun in spring. In 1908, copulation was observed April 24 and eggs were found May 2. In 1912, eggs were found May 5. The length of the egg-laying period is indefinite, seeming to depend on the number of copulations happening to the female, of which there may be several in each case. At the commencement of the egg-laying period the abdomen of the female is much distended. When working without interruption, a female will excavate from 2 to 10 cells per day and deposit an egg in each. A completed brood chamber may contain from 80 to 160 eggs.

In the territory studied, eggs can be found from about the 20th of April until October 1. The fully matured, curved embryo eats its way out through the shell wall at or just above the base of the egg and commences feeding on the under surface of the bark. In dimensions, the new-born larva is slightly longer and a little more slender than the egg. It rests for a short time lying in a slightly curved position in its burrow. The white color of the new larva is soon suffused with pinkish, owing to the bark particles in the digestive tract. Feeding is slow at first and the larvae are several days getting away from the egg-shell, but increase the rate of progress as they grow older. The excrement fills the egg-shells as the larvae gradually work out and away from them, thus permanently marking the location of the shell from which each larva issues. When the bark is removed, the course of the burrow is plainly marked by the line of brownish excrement which completely or partially fills its entire length.

The larvae excavate their galleries at right angles to the parent burrow, generally following the grain of the wood. For some distance out, the galleries lie side by side and parallel to each other, but at a distance of one-half to three-fourths of an inch from the parent burrow, they commence to diverge so that the terminal ends and, therefore, the exit holes form an irregular ellipse around the brood chamber. The length of the larval galleries is from 1.5 to 2.875 inches. The larvae require from 25 to 30 days to become grown, and, when fully matured, they burrow outward making a pupal cell just beneath the outer surface of the bark. They continue development for two or three days in their cells, then, having finished feeding, they void their excrement, becoming clear white instead of pinkish, cast their skins and become pupae.

The pupae are quite active, moving the abdomen continually back and forth. They gradually assume a dark color, and in from 4 to 10 days shed their skins, producing some very tender beetles. These beetles harden up within 4 to 6 days and feed from the walls of the pupal cell. When well hardened, and sometimes before, the beetles cut their way through the bark to the outside, but are not apt to leave the cells until a period of several days to two weeks or longer has elapsed.

NUMBER OF BROODS

There are two complete broods per year in northern Ohio, the summer brood appearing about July 20, reaching a maximum during the latter part of August and gradually dwindling to a few stragglers in late September and early October; and the fall or hibernating brood which yields adults in October and November.

From October until freezing weather, the fall adults are steadily emerging and migrating to growing trees. They enter such trees through rough places on the bark and excavate short burrows from one-fourth to one-half inch or more in length. These burrows are closed in their outer course by the exudation of gum and the beetles utilize the innermost ends as hibernation chambers. The latest formed or retarded adults hibernate in their pupal cells, not cutting their way out until the next spring. Hibernation, therefore, occurs in both living and dead wood, the emerged beetles making cells in the former, and the retarded beetles remaining in their pupal cells in the latter. There is a little overlapping of the summer and fall broods, so it seems there is no time in the year when at least a few beetles cannot be found, if infestation is general and severe. The very late beetles of the summer brood probably do not oviposit in the fall but hibernate with the fall beetles in living wood and reproduce in the spring. The spring brood is at its maximum in numbers and activity in late April and during the first two or three weeks of May, terminating almost wholly by early July, though an occasional specimen will linger until after the appearance of the summer brood in the latter part of the month.

The following table prepared by Mr. Wilson, shows the varying rate of emergence of the summer brood:

TABLE II. Emergence of summer brood of beetles of *Phloeotribus liminaris*

Date[1]	Beetles reared in cages	Beetles from insectary on window screens	Date	Beetles reared in cages	Beetles from insectary on window screens
July 16	2	60	August 25	40	....
" 23	..	30	" 26	60	1,500
" 24	..	74	" 27	86	1,000
" 26	83	....	" 28	69	600
" 27	..	300	" 29	72	1 000
" 28	32	....	September 3	154	200
" 29	30	....	" 4	111	...
" 31	82	450	" 5	40	200
August 4	68	....	" 7	67	75
" 5	..	350	" 10	18	...
" 6	84	500	" 11	38	...
" 6	151	....	" 13	91	40
" 12	258	450	" 15	37	...
" 15	...	1 200	" 17	29	...
" 16	...	750	" 19	12	...
" 17	...	750	" 22	32	...
" 18	317	1 750	" 24	21	...
" 21[2]	327	2 500	" 29	7	...
" 24	129		October 2	4	...

[1] The first column shows beetles actually counted and taken from a breeding cage; the second row of figures shows, somewhat estimated, numbers of beetles gathered on screens at windows. All counts made between 4 and 6 p. m.

[2] This table shows August 21 to be the date of maximum emergence of beetles.

FOOD PLANTS

Mr. Wilson recorded peach, cherry, wild cherry, mountain ash and plum as host plants. He did not find it on plum in the field, but reared it on plum trimmings in a breeding cage, readily getting the

second generation in this manner. Mr. King recorded it from peach, cherry, wild cherry and wild plum growing in the field. Its preference seems to be for peach and cherry, next for wild cherry.

PARASITES

The only parasite found working on this species was a tiny nematode worm, located by Mr. King within the body cavity. The same or a very similar nematode was also found in the body of *E. rugulosus.* Efforts were made by Mr. Wilson to breed some of the parasites of *E. rugulosus* on *Phloeotribus liminaris*, but without success. Where the two beetles were found breeding in the same wood and the parasites of *E. rugulosus* were abundant, there was a corresponding diminution in the numbers of *E. rugulosus*, whereas, *P. liminaris* issued in numbers corresponding to the numbers of larval chambers. Mites, found in considerable numbers in the burrows and clinging to the hairs of the beetles, are apparently not parasites but feeders on the excrement and other decaying matter within the burrows. They attach themselves to the beetles in order to procure easy transportation from one place to another.

REMEDIES FOR BARK BEETLES

So similar are the habits, life-histories and economy of the two species of bark beetles, *E. rugulosus* and *P. liminaris*, that the same measures of prevention and remedy apply to both, and efforts directed especially against one of them will be found to be almost equally effective against the other.

1. **Create an Unfavorable Environment for Propagation:** As indicated in the Introduction to this bulletin, old and neglected orchards that have died from the effects of San Jose scale attack, or which for any reason have become unprofitable and have been allowed to remain standing without care, furnish an ideal incubating ground for these beetles. Large areas on the Marblehead peninsula, adjacent to the villages of Marblehead, Lakeside and Gypsum, planted to peach orchard, are underlaid with valuable lime deposits, and much of this land was purchased a few years since by various syndicates. After these purchases, in some cases, especially where the orchards were infested with San Jose scale, they were totally neglected and allowed to die as fast as they would. These dead and dying trees, with just a little life in them, exactly supplied the conditions most favorable for the multiplication of both species of bark beetles. As a consequence, the insects were soon spread out over all the contiguous peach-growing country, and, when the supply of unhealthy trees was exhausted, they turned their attention to

some of those that were healthy, and by repeatedly attacking them, caused such losses of gum and sap that the trees gradually weakened, whole orchards of good trees being at times threatened with final destruction.

Trimmings and woodpiles constitute a similar source of danger. Many of the orchardists try to conserve the waste products of their farms and wish to utilize the trimmings from their peach trees, also dead trees, for stovewood. Such wood may be profitably burned during the winter months, but, if infested, should not be kept later than the middle of April when the adults of *P. liminaris* become active. If only *E. rugulosus* is present, the woodpile may be continued until the middle of May, but all infested wood, not used up in stoves by the dates specified, should be burned in the open to prevent the escape of any beetles to the orchard. Many cases are known of orchards becoming infested from woodpiles where peach wood was carried over from year to year. We have frequently found several rows of trees, adjacent to the woodpile, suffering greatly, the severity of the attack gradually diminishing as the distance between the woodpile and the trees increased. One of the peach growers in the Marblehead district attributed the commencement of the great outbreak of bark beetles in that territory, about 1906-07, to the use of peach brush as a barrier to protect the shore line near Ohlemacher' Landing against the wash of Lake Erie. The brush was piled in a long windrow along the shore, just south of the terminus of the Toledo, Port Clinton and Lakeside Trolley Line, to prevent the destruction by erosion of a peach orchard adjoining the shore. Several rows of trees in this orchard were killed by bark beetles the following summer, and within two or three years the whole orchard was practically dead. Dead peach wood seems to offer suitable conditions for developing brood as long as the bark adheres to the wood, provided sufficient moisture is present. Messrs. Wilson and Goodwin found piles of dead infested wood in June and July, 1908, well covered with grass of two seasons growth, and, therefore, readily holding considerable moisture. This wood was as full as it could well be of the larvae of both species of bark beetles, thus proving that they breed readily in wood that has been dead and piled on the ground for considerably over a year.

It is obvious that all orchard trees should be regularly trimmed each year, and all dead and sickly limbs, branches and stubs cut away and burned. Very weak trees, as well as dead ones, should be removed and burned. Trees dying late in the summer may be left as traps and cut late in the fall when full of larvae. Trees dying in the spring should either be burned at once or else left as

traps until filled with larvae, when they should be consumed; also, dying trees, of varieties susceptible to infestation, in nearby wood-lots, should be cut down and burned. If whole neighborhoods would cooperate together in these clean culture measures, never through neglect omitting any of them, a general outbreak of these beetles, or even notable damage by them, would be very improbable, in fact, almost impossible.

2. **Cultivation and Fertilization:** Since both of these measures stimulate growth and increase the sap flow, both help the trees to maintain a condition that is unfavorable to production of bark beetle brood, and the wounds made in such trees by the adults to feed are more quickly repaired than is the case with uncultivated and starved trees, when attacked. An abundance of barnyard manure is generally the best fertilizer. However, we have used some combinations of mineral fertilizer on our experimental blocks and have found that they possess some value. On poor land, they would doubtless have proved of much greater help.

3. **Whitewashing and Similar Treatments as Preventives of Attack:** Whitewashing has proved of much value in preventing attack, but under some circumstances its effectiveness is much diminished. We have never known of trees in good general health that did not successfully throw off an attack, if carefully white-washed two or three times per season through a period of two or three years. Old and decrepit orchards can generally be rejuvenated if severely headed back to stubs, cultivated. and fertilized, and then regularly whitewashed for a few years. If there is a nearby exhaustless breeding ground for bark beetles, this treatment may not avail. Thus, we have sometimes had blocks of trees so circum-stanced that they continued to suffer and be reinfested with brood, notwithstanding a heavy coat of whitewash. Whitewash does not interfere in any way with larvae already beneath the bark, but fills up rough places in the bark, thus making it difficult for the females to satisfactorily place their eggs. Also, these beetles, in common with most insects, dislike to expose themselves on a white surface. Whitewash may be made thin enough to apply with a spray pump, but it requires two or three successive applications, a day or so apart, to get a really protective coating. About 4 pounds of table salt to each 50 gallons of spray increases the sticking qualities. Most of our applications consisted of a thick whitewash, with one-fourth pound of salt to each 3 gallons, and these were made with a broom to the trunks and the larger branches. If the beetles are excessively numerous in the neighborhood, make three applications during the season, the first by or before April 1st, the second about the middle of July, and the third by or a little before October 1st.

Of the other washes tried, Carbolineum Avenarius has been the most successful. Used in concentrated form this material is too expensive for use, and is dangerous to the life of even healthy trees. We have seen several trees that were killed outright by being painted with the undiluted material during the dormant winter period. In other cases, trees have survived the same treatment under apparently the same conditions without perceptible harm.

Mr. Wilson found, in some instances, that the larvae in their burrows had been killed where a coating of Carbolineum or of Carbolineum emulsion had been given the bark, while the trees seemed uninjured. Since no observers have since been able to confirm this conclusion, and several have had equally good opportunities to see effects, we believe that results are variable with this mateirial, or else, less probably, that something besides the Carbolineum must have caused the death of the larvae examined by Mr. Wilson. Emulsions of Carbolineum have apparently been somewhat more effective than whitewash for repelling the insects, and in case of severe attack, the extra cost seems to us to be warranted by the results, especially where valuable trees are endangered. The most successful formula we have used for making an emulsion is as follows:

Dissolve 4 pounds of of naptha soap in 4 gallons of water and, while this is boiling hot, remove from the fire and add one gallon of Carbolineum Avenarius, agitating with a force pump, or for small quantities with a rotary egg-beater, exactly as if preparing kerosene emulsion. When well emulsified, add 3 gallons of hot water and apply to the trees while warm. Keep face and hands well protected and horses well blanketed when applying this emulsion, and work only on the windward side of the trees, as it is very penetrating and is likely to cause blistering and sloughing off of the skin, should this become wetted with it. These emulsions of Carbolineum seem not to have injured the trees in any case.

EXPERIMENTAL DATA SUPPORTING CONCLUSIONS AS STATED

The full program of 43 plot tests conducted by Mr. Wilson in 1908 is shown herewith, the number of trees used in each plot being mentioned in connection with each treatment:*

1—Used 16 trees. One part by weight of lime; 2 parts by weight cement; milk used to make a stiff whitewash and applied with a broom to 96 trees, 32 of which were used in experiment No. 2, with the addition of manure. Thirty-two more were used for experiment No. 3, with an application of commercial fertilizer. Sixteen trees of each plat were given a second application, forming experiments Nos. 4, 5 and 6.

*Bull. 68, Pt. IX, Bureau Ent., U. S. D. A.

Date of application, April 9, 1908.

2—Used 32 trees of experiment 1. Barnyard manure spread in a 7-foot circle about each tree, to get value of fertilizers.

Date of application, April 9, 1908.

3—Used 32 trees of experiment 1. Commercial fertilizer applied in a 7-foot circle about each tree.

Cement applied April 9, 1908; fertilizer applied May 7, 1908.

4—Used 16 trees of experiment 1, making a second application.

First application, April 9, 1908; second application, July 3, 1908

5—Used 16 trees of experiment 2, making a second application

First application, April 9, 1908; second application, July 7, 1908.

6—Used 16 trees of experiment 3, making a second application.

First application, cement, April 9, 1908; fertilizer, May 7, 1908; second application, July 3, 1908.

7—Used 2 pounds fish-oil soap per gallon of water (dissolving soap in boiling water) for first application. Used 1 pound of soap to 6 gallons of water for second treatment. Twenty-four trees treated, 16 to be used for experiments 8 and 9.

First application, April 10, 1908; second application, July 7, 1908.

8—To each of 8 of the 24 trees treated in experiment 7 added barnyard manure to find value of fertilizers.

First application, April 10, 1908; second application, July 7, 1908.

9—To remaining 8 trees of experiment 7 added commercial fertilizer, 4 pounds to each tree, spreading in a 7-foot circle.

Fertilizer added May 7, 1908; second application, July 7, 1903.

10—One gallon Carbolineum mixed with 20 pounds of flour, then 25 gallons water added to make emulsion; sprayed 72 trees, 48 of which were used for experiments 11 and 12 to get value of fertilizers.

Sprayed whole tree April 10, 1908; sprayed trunks and limbs below foliage July 6, 1908.

11—Used 24 trees of experiment 10, and added barnyard manure, spreading in about tree in 7-foot circle.

First application, April 10, 1908; second application, July 7, 1908.

12—Used 24 trees of experiment 10, and added 4 pounds of commercial fertilizer to each tree, spreading it in 7-foot circle about tree and harrowing in.

First application, April 10, 1908, second application (3 pounds commercial fertilizer) July 6, 1908.

13—Used 1 gallon Carbolineum, emulsifying it with 4 pounds soap (dissolved in 4 gallons of water) and diluting the whole to 8 gallons; sprayed 144 trees, 96 of these to be used in four more experiments.

Application made April 10, 1908.

14—Used 48 trees of plat 13. Sprayed twice.

First application, April 10, 1908; second application, July 6, 1908.

15—This was to have been a third spraying, but was found unnecessary on account of absence of beetles.

16—Used 24 trees of experiment 13. Barnyard manure (to get value of fertilizers) spread about trees in a 7-foot circle.

First application, April 10, 1908; second application, July 6, 1908.

17—Used 24 trees of experiment 13. Commercial fertilizer added 4 pounds to each tree, spread in a 7-foot circle to get value of fertilizer.

First application, July 3, 1908, (3 pounds fertilizer).

18—Sprayed 6 trees with pure Carbolineum without seeming injury to the trees.

Application made April 9, 1908.

19—Used 25 pounds of lime, 15 pounds sulfur, 6 pounds resin, 3 pounds arsenate of lead, and 50 gallons of water. Applied the mixture with a brush to trunks and large limbs of 6 trees.

Application made April 17, 1908.

20—Same as experiment 19, plus barnyard manure. Two of 6 trees in experiment 19 used.

Application made April 17, 1908.

21—Same as experiment 19, plus commercial fertilizer. Two of 6 trees in experiment 19 used.

Application made April 17, 1908.

22—One gallon Carbolineum, 1 gallon lard and 25 pounds resin. Painted trunks and larger limbs of 5 trees.

Application made April 17, 1908.

33—One bushel tobacco stems boiled for one hour in 4 gallons of water; one-half bushel stone lime and 4 quarts salt added; one-half pint crude carbolic acid used in each 12 quarts of the liquid. All gum and rough bark scraped from the trees and the paint put on with a broom.

Applied the mixture of 72 trees April 22, 1908.

24—Used 24 trees of experiment 23. Same treatment, plus barnyard manure spread in 7-foot circle about each tree.

Application made April 22, 1908.

25—Used 24 trees of experiment 23, plus commercial fertilizer spread in 7-foot circle about each tree.

Applied April 22, 1908; fertilizer applied May 7, 1908.

26—One gallon Chloronaptholeum, emulsified with 4 pounds of soap (dissolved in 4 gallons of water); then added water enough to dilute 25 gallons. Sprayed 120 trees.

First application, April 22, 1908; second application, July 7, 1908.

27—Used 24 trees of experiment 26; added barnyard manure, spreading it in a 7-foot circle about each tree.

First application, April 25, 1908; second application, July 7, 1908.

28—Used 24 trees of experiment 26, adding commercial fertilizer, 4 pounds to each tree, spreading it in a 7-foot circle.

First application, April 22, 1908; fertilizer added May 7, 1908; second application, July 7, 1908 (3 pounds fertilizer added).

29—One gallon Chloronaptholeum mixed with 22 pounds flour to emulsify, added to 30 gallons water, and put on 120 trees with spray pump.

First application, April 17, 1908; second application, July 13, 1908.

30—Used 24 trees of experiment 29; added barnyard manure to get value of fertilizer.

First application, April 17, 1908; second application, July 13, 1908.

31—Used 24 trees of experiment 29, adding commercial fertilizer, 4 pounds to each tree.

First application, April, 17, 1908; fertilizer added May 7, 1908; second application, July 13, 1908.

32—Six pounds arsenate of lead to 50 gallons water; 3 pounds lime added to neutralize the free arsenic. Put on heavy spray; pruned trees before spraying; 170 trees sprayed.

First application, April 20, 1908; second application, July 13, 1908.

33—Boiled lime and sulfur spray (15 pounds lime, 15 pounds sulfur, 50 gallons water.) Excessive application made to 200 trees.

First application, April 24, 1908; second application, July 13, 1908.

34—Self-boiled lime-sulfur wash (15 pounds lime, 10 pounds sulfur, 50 gallons water). Water added slowly so as to prevent burning, stirring vigorously during the process. Sprayed 300 trees.

First application, May 18, 1908; second application, July 13, 1908; to trunks and larger limbs.

35—A stock solution of kerosene emulsion, 20 percent strength, was made and to each gallon of stock solution 2½ gallons rain water were added. Applied with spray pump.

Application made April 20, 1908.

36—Fumigated 6 trees with hydrocyanic-acid gas for one hour, first scraping off all gum and rough bark. Treatment given August 24, 1908.

37—Tree tanglefoot. Put bands around 12 trees and then covered bands with tanglefoot. Application made April 25, 1908.

38—Renovation block. Pruned back severely about 100 trees (girdling 4 trees for traps and not treating them further); applied fertilizer twice and kept trees cultivated all summer.

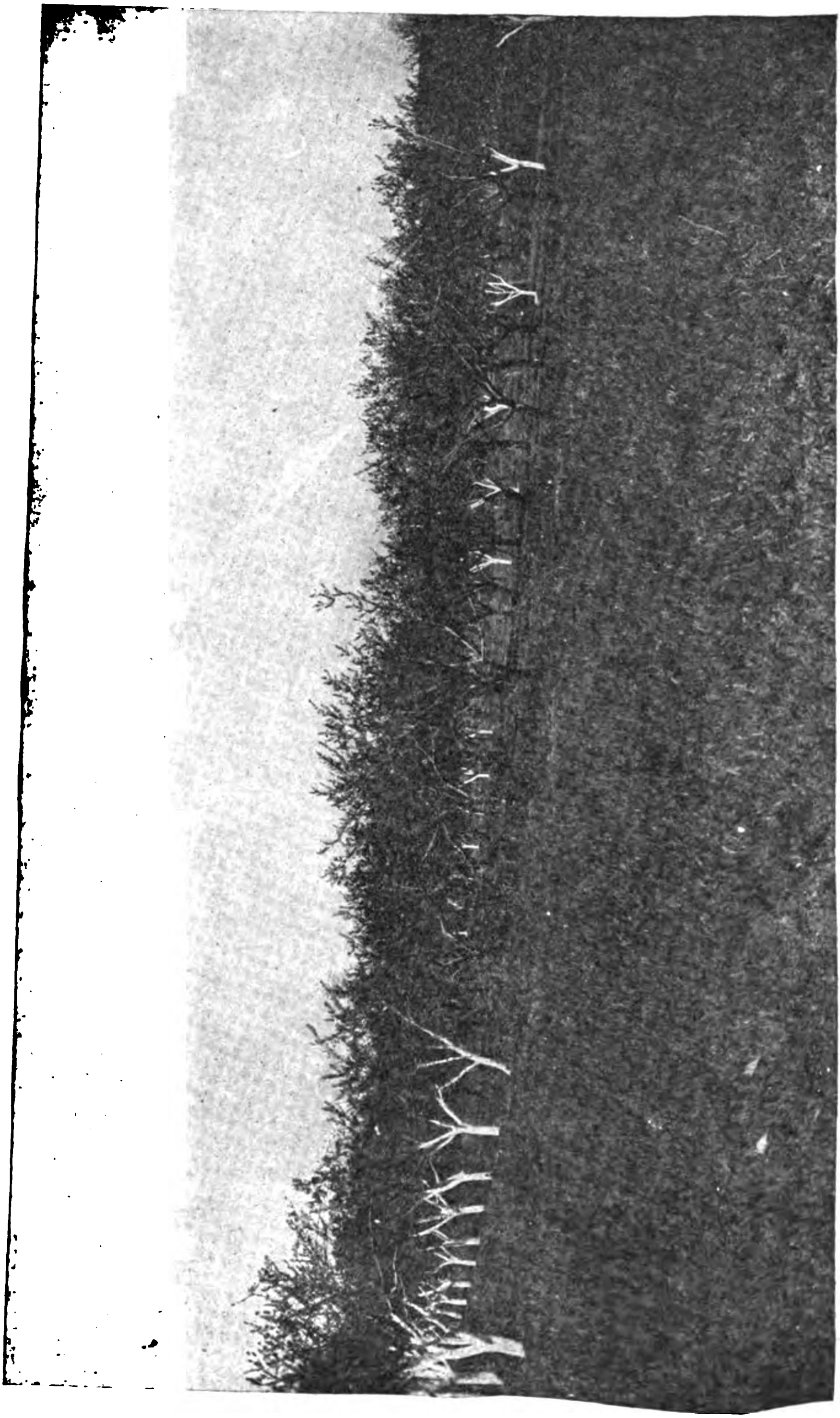


Plate IX. Photograph in Experimental Orchard; whitewashed blocks and others treated with Carbolineum emulsion. *Photo. by L. L. Scott*

First application, April 19, 1908; fertilizer added May 7, 1908 (4 pounds per tree). Second application, July 3, 1908 (3 pounds fertilizer added).

39—A duplicate of experiment 17 tried on 200 trees; pure whitewash was applied as a second treatment.

Emulsion applied April 21, 1908; whitewash applied September 1, 1908.

40—Placed pieces of branches as traps in trees of small orchard to see if beetles would settle on them.

41—One-half barrel kerosene emulsion used instead of water to make a good, stiff whitewash, applying with broom to plat of 200 or 300 trees.

First application made May 4, 1908; second application, July 9, 1908.

42—One gallon of Chloronaptholeum added to every barrel of whitewash used. Whitewash made as thick as possible and applied with a broom to plat of about 200 trees.

First application, May 6, 1908; second application, July 9, 1908.

43—One gallon of Avenarius Carbolineum added to each barrel of whitewash used; whitewash made as thick as possible and applied with a broom to a plat of about 200 trees.

All fertilizer used in above experiments was of the following formula:

Phosphoric acid	8	percent
Nitrogen	5	"
Potash	2	"

All trees fertilized made a growth of rich green foliage and the trees looked healthy, yet many of them were again attacked by the beetles.

Mr. Wilson summed up the results of this set of experiments as follows:

"The first 6 experiments seem to show that whitewash acts as a repellent, not affecting the beetles once they are in the bark, but if the trees are kept well coated the beetles do not seem to attack the whitewashed parts. The addition of fertilizer to the trees causes a strong flow of sap which, exuding through the burrows, seems to repel the beetles. The treatments given in Nos. 7, 8 and 9 seemed to have no effect whatever. In experiments 10, 11 and 12 the beetles in the tree at the time of application appeared to be killed, but the mixture did not act as a repellent and beetles settled on the trees again in a short while. Experiments 13, 14, 15, 16 and 17 were more promising, and two applications a season would undoubtedly keep the beetles down. The expense of these

experiments, however, makes them impracticable as tried here. In experiment No. 18 all beetles attacking the trees at the time of application were killed, and others did not settle on the trees during the entire season.

The cost of materials used in this experiment, however, makes the treatment impracticable. Experiments 19, 20 and 21 had no effect whatever, neither killing the beetles in the trees nor repelling others. In experiment 22, all trees treated were killed. Experiments 23, 24 and 25 gave very good results, the whitewash sticking well and the beetles not attacking the trees until long after the whitewash had fallen off. Experiments 26, 27 and 28 seemed to have had very little effect on the beetles in the bark and did not repel later attacks. Experiments 29, 30 and 31 failed to give any beneficial results, the emulsion being very poor, as the oil became partly separated from the mixture before the latter could be applied. Experiments 32, 33, 34, 35, 36 and 37 gave only negative results, neither killing the beetles in the burrows nor repelling later attacks. In experiment 38 a plat of 100 trees was used. Fifty of the trees were very severely cut back and 4 or 5 of them, being too weak to recover, died. The other 50 trees were sprayed with lime-sulfur wash. At the end of the season the pruned trees had produced a strong, healthy foliage and the beetles were attacking them but little. The untrimmed trees were badly attacked and had thrown out a scant, sickly-looking foliage. Experiment 39 gave satisfactory results. All of the beetles in the trees at the time of application were killed and no more settled on them until about the last of September; then a few having settled, the trees were whitewashed and further injury was stopped. The cost of this treatment, as made here, prevents it being practicable for a large orchard unless the amount of material used can be reduced with equally good results for the weaker emulsion. Experiment 40 showed that the beetles attack the trees in which these cut branches were placed without settling on the cut branches. Experiments 41, 42 and 43 showed the most practicable, and at this time the most likely remedies. These are the combinations of a whitewash and an oil, the whitewash probably being the main factor in repelling the beetles. The cost of these experiments was 1¼ cent per tree for each application. The trees in these plats, while not entirely free from further attack during the season, suffered considerably less than surrounding plats of trees."

The following year Mr. L. L. Scott made applications on a much larger scale of those remedies which Mr. Wilson had found most promising. The general plan of experimentation in 1909 was as follows:

LARGE SCALE EXPERIMENT

1—Cut back a badly infested block of trees to stubs of main limbs, fertilize and whitewash.

2—Fertilize and whitewash a slightly infested block.

SPECIAL TREATMENTS FOR BADLY INFESTED BLOCKS

3—Cut back to stubs.

4—Cut back to stubs and fertilize.

5—Fertilize, with ordinary sort of trimming.

6—Same as 4 with whitewash added.

7—Trim in ordinary way and whitewash.

8—Cut back and whitewash.

9—Spray with 12 percent Carbolineum emulsion, and trim in ordinary way.

10—Same as 9, but cut back to stubs.

11—Same as 9, but cut back and fertilize.

12—Check.

Each block used in these experiments approximated one-half acre or more of trees. Mr. Scott summed up the results of his season's work as follows:*

"A large number of remedies were tried during the season of 1908 and during the past season only those were tried which gave best results the previous year. Among these, several seemed to give about equally good results; but one appeared to do a little better than the rest, and it may be well to present that here.

Two blocks of Elberta trees were selected and on one an application of a seven percent soap emulsion of Carbolineum Avenarius was made, and on the other a twelve percent emulsion was applied, and since both of these blocks grew so well, had such thrifty green foliage and seemed so free from beetle attack, it appeared that these emulsions were about the best remedies tried.

Carbolineum is a wood preservative and is corrosive to the flesh, so naturally can not be applied when trees are in foliage else the leaves will all be burned, so that the applications necessarily have to be made when the trees are still dormant, or at least before the leaves open in the spring, and then the spray should only be directed against the trunk and bases of the larger limbs of the tree, or there may be danger in injuring some of the unopened buds. A Bordeaux nozzle may be used, and was quite satisfactory if held with the spread of the spray parallel to the trunk and limbs. As a further remedy, it is well to follow the practice of many and whitewash the trees a little later in the spring, and again in the late summer, if there is

*Forty-third Annual Report, Ohio State Horticultural Society, January, 1910.

time; the whitewash not only acts as a preventive against the beetle but it also serves to keep the bark of the tree smooth, and in addition it gives the orchard a nice, clean appearance, which is a point worth considering by any grower.

If trees are so badly infested by the beetle that they cannot be saved in any way, they should be dug out during the winter and burned immediately, as in this way thousands of hibernating larvae will be destroyed, which would cause a more serious infestation the following year if the brush were allowed to lie around unburned.

Where trees are quite badly infested, but there is a possibility of saving them, cut out all infested parts and severely head back the entire tree; then fertilize well with some good, complete commercial brand, and give the tree thorough cultivation in order to stimulate as healthy a growth as possible, so the tree may recover from the attack.

Finally, with healthy trees to begin with, give them all the care and attention they demand, feed them, care for them as you would expect to for any other living thing on the place, and it is altogether probable that an attack will be postponed if not entirely averted."

In 1907, a vigorous young peach orchard of about 100 trees at Longley, Ohio, was severely attacked by *S. rugulosus*. An old apple orchard nearby had been killed by scale and the trees had been gradually cut down and the wood kept for stovewood. The beetles started with these conditions and bred rapidly. The peach orchard had never been very scaly and was sprayed regularly with lime-sulfur wash. Notwithstanding the general good health of the trees a few had died from repeated attacks by the beetles and many were gumming badly. By advice of the writer, the owner of the orchard painted the trunks and larger limbs with a stiff paint made by mixing together Portland cement and water. By the spring of 1908, the condition of the trees was greatly improved.

April 10, 1908, one-half of the orchard was painted with water-cement, and of the remaining half, one tree was painted with pure Carbolineum, 5 others were painted with almost pure Carbolineum which separated from and floated on the top of an imperfect emulsion, while the remainder were sprayed by means of a hand pump with a 12½ percent good and stable emulsion of Carbolineum.

These treatments were repeated July 11, 1908, by Mr. H. T. Osborn. At this date, the tree which had been painted with pure Carbolineum was practically dead, and the other 5 that received treatment with Carbolineum very little diluted, were in an unhealthy, bark-bound condition. All other trees were in excellent condition, and the beetles had apparently abandoned the orchard altogether, quitting the checks as well as the treated trees.

In July, 1910, Mr. Whitmarsh whitewashed a block of trees in the Duroy and Yule orchard which were being attacked by bark beetles, using a spraying machine to make the application. October 26, 1910, he entered the following note: "Today I visited the orchards of Mr. Yule and found the orchard which I had sprayed thoroughly in July, with whitewash, to be badly infested with beetles on the two north rows and not quite so badly infested on the third row from the north side; south of this I could find but few beetles. The probable cause of this infestation was due to the stumps of old trees north of the above orchard and only separated from it by a narrow driveway which is literally swarming with beetles, both *P. liminaris* and *E. rugulosus*. This infestation could probably have been avoided partially or altogether, by thoroughly whitewashing in early September before the hibernating brood of *P. liminaris* emerged. They had bored into the bark very extensively by October for hibernating or feeding, an earlier date by two weeks than such wholesale burrowing is usually done."

The history of a number of orchards in the infested neighborhood confirm the results obtained in our experiments, or in some cases the statement can be reversed, and it should be said that our experiments confirmed the results obtained by the orchardists.

In Mr. Scott's notes for 1909, I find the following entries:

July 1. "One block of trees (back of Mrs. S. L. Kinglets) which was badly infested last year, but received treatment, shows scarcely any beetles at all."

July 30. "In looking over the experimental orchard, I find that some of the weaker trees show some beetles attacking them, noticeably on those parts of the tree which are partly dead or dying. On other more healthy parts of the same trees the beetles have made attacks but in most instances are repulsed by the copious exudations of sap. Such attacks usually extend well into the top and smaller limbs of the trees and in several instances the loss of sap has been great enough to so weaken the trees that egg burrows can be completed without the beetles being driven out by the flow of sap.

One tree, on the row receiving only whitewash, is quite badly infested and will die, notwithstanding the treatment given. This tree is situated in a low and wet spot which contributes to lower the vitality of the tree so the beetles can obtain a foothold. Several of the weaker trees which received 12 percent Carbolineum emulsion show attack more or less serious, as do also weak trees treated with Chloro-naptholeum emulsion and with whitewash cement."

"Out of the block treated with 12 percent Carbolineum emulsion, 3 trees died and 2 others were weakened, but are now recovering.

The other trees in this block were not injured at all. On the contrary, the foliage seems to be a darker green and more healthy and luxuriant than it is on some of the other trees, and the fruit is abundant and maturing in good form. Trunks and limbs are smooth and healthy, but are coated a dark brown. This results from a well-mixed emulsion, applied while warm. The emulsion killed the small twigs (more or less tender) on the trunks and near the bases of the larger limbs. Older and more mature wood was not injured. The 3 trees killed by application of the 12 percent Carbolineum emulsion were cut down today and placed in the out-door insectary for beetles to emerge. The main limbs and many of the smaller ones, even to the top of the tree, were full of larvae in all stages, from those just hatched to full grown ones, and some pupae were found. Cutting into some of the burrows, both *E. rugulosus* and *P. liminaris* were found, the former probably being most numerous. The block of trees on the Wolcott place, treated March 1, by Mr. W. H. Wright, with pure Carbolineum are all dead. The trees have the appearance of having been varnished. Cutting into the bark, the liquid seems to have penetrated to the living cells and killed the protoplasm."

In March, 1908, the author was called to visit the orchard of Mrs. T. S. Johnson, near Gypsum, Ohio. A block of this orchard adjacent to the woodpile was suffering severely from an attack of bark beetles, the insects evidently issuing from the wood, which was peach, of one or two year's harvesting. In 1908, the diseased trees were cut back and treated with whitewash or Carbolineum emulsion. The following year, 1909, Mr. L. L. Scott entered the following observations, July 26th:

"In looking over this orchard I find that as a general thing the treated blocks are comparatively free from attack of bark beetles. The stubs cut back and sprayed last fall and spring with 12 percent Carbolineum emulsion are all dead, only one or two showing any green shoots and these are dying. Blocks not cut back but sprayed this spring with 12 percent Carbolineum emulsion seem healthy; they have a dark green foliage and very few beetles can be found on them, except on some limbs partly dead and, even here, they are not numerous. A few places were found where beetles had started to bore into healthy limbs, but they had only eaten through the cortex and then quit. No sap had exuded, so it seems probable that the beetles were repulsed by the odor or by the taste of the Carbolineum in the bark. Blocks of trees cut back and whitewashed are sending out a vigorous growth of new shoots and all seem to be living. No beetles could be found on the whitewashed trees, except where a

limb was dying and was so far gone that it had failed to send out any new growth. Remainder of orchard, which was whitewashed without cutting back, is thrifty and few beetles can be found, except on weak, dying limbs. In general, the treatment seems to have been quite effective."

June 2, 1910, Mr. Whitmarsh entered notes as follows: "Visited Mrs. T. S. Johnson's estate and found the adult beetles of *P. liminaris* working to some extent in a few trees, but was unable to find any of *E. rugulosus*." Oct. 24, 1910, he made observations as follows: "Visited Mrs. T. S. Johnson's and went through the peach orchards with Mr. Adams, who is in charge of them. The beetles were working to some extent, but, on the whole, did not seem to be doing so much damage as they did in the spring and summer. The trees treated with whitewash, and those treated with Carbolineum, and those not treated at all seem to show very little difference as regards bark beetle work. Of the small number of trees treated with the Carbolineum, as noted above, several had died, but I hardly think that it was due to the Carbolineum as the trees were very weak when treated, and probably would have died regardless of any or no treatment. The healthy trees show no ill effects of the spray."

Mr. Whitmarsh made the following record for the Dailey orchards: "July 7, 1911, I visited the large peach orchards of F. W. Dailey & Son, and found that they had the beetle under control. They have accomplished this by thoroughly applying the following mixture three times per year for the past five or six years: One bushel lime, 40 gallons water, 2 gallons Rex lime-sulfur solution, and a couple of handfuls of salt. Mr. Robert Dailey, with whom I talked, said that the orchard was badly infested five years ago, but at the present time a beetle can hardly be found. He expects this year to make only two applications of whitewash, deeming the third unnecessary with the beetles so nearly exterminated."

Mr. Geo. Mallory reported good results from the use of one pint of pine tar to one barrel of whitewash.

Mr. J. L. King made a trip, May 1, 1912, over the ground on which Mr. Wilson and Mr. Scott worked and reports as follows:

"The orchards of Duroy and Yule were thoroughly examined and only two beetles could be found in an old Salway orchard. From Duroy's to Jacobson's many neglected orchards were observed, but only a very few beetles (*P. liminaris*) found. On a wild cherry at Mrs. Jacobson's, quite a few burrows were located in the deep furrows of the bark. Farther east a few more beetles were found in cherry, but in all cases the numbers were small. The orchards of the Kelley Island Lime Co. were all dead, showing the carvings of

P. liminaris in great numbers. They were too old to sustain beetles or larvae any longer. Many of these had been cleared away and burned. Mrs. Jacobson's orchard, which was whitewashed, pruned and fertilized, was doing nicely and had made a vigorous growth in 1911. Mrs. Jacobson states that this orchard was badly infested with bark beetles in 1908, so much so that it was turned over to Mr. Wilson for experimental use. He whitewashed it, pruned it severely, and fertilized it. This strengthened it to such an extent that the bark beetles were entirely resisted."

The beetles appeared in some numbers in the orchards of Mr. S. R. Gill and also those of Mr. Wm. Miller, but soon disappeared. Proper care, cultivation, fertilization, trimming and spraying, with a judicious use of fire, probably operated strongly against the beetles in these orchards, but these routine measures were supplemented to some extent for at least one or two seasons with some whitewashing, a small quantity of Carbolineum being sometimes added to the whitewash.

These experiments and observations confirm the efficacy of the earlier remedies recommended for these insects. Thus, in the Rural New Yorker, May 19, 1883, W. L. Deveraux writes concerning *P. liminaris*: "By simply deferring pruning until early July we may be sure of finding the whole family at home, including the entire progeny for the next year, or the trimming off of all dead limbs may be done in winter or spring and the brush may be piled up in the orchard and await the planting of the brood chambers before applying the torch. They choose trees having rough bark; but they can enter the smoothest twig or young growth as I have observed them do in experimental tests. Thus, if they are headed off by the presence of tar-lime or soap on the trunks, they will repair to the branches and forks."

Dr. James Fletcher in the 26th Rept. Ent. Soc., Ontario, 1895, makes the following observations: "The Peach Bark Borer (*Phloeotribus liminaris*) which for some years has done so much harm in the peach orchards of the Niagara peninsula, has this year been successfully treated by Mr. C. E. Fisher of Queenstown. Noticing that the perfect beetles became active very early in the spring, he would wash his trees with a strong alkaline wash to which carbolic acid had been added. He made his wash as follows: Five pounds of washing soda, three quarts of soft soap and enough water to make six gallons. Air-slaked lime was then added sufficient to make it of the consistency of thick paint. To all this was added three tablespoonfuls of Paris green and one ounce of carbolic acid. This mixture was applied with a whitewash brush, thoroughly

covering the entire trunk of the tree and a few inches up on the limbs. Mr. Fisher reports that at the end of the season he is quite satisfied with the results of the treatment. It would appear from what I have just said, that two applications of this mixture, the first one being made as soon as the beetle becomes active, sometimes as early as March, and another six weeks later, would provide us with an effective remedy for this little pest which for some years has done considerable harm in our Canadian peach orchards."

PIN HOLE BORERS

There are a considerable number of Scolytid beetles, other than the two species which we have treated at length, that work in the heartwood of trees as well as in the sapwood, most of them having a long list of hosts besides orchard trees. The external openings of their burrows resemble those of the bark beetles previously described, but on the average are smaller and suggest pin holes rather than shot holes. These beetles which penetrate the heartwood are less to be feared than those which have the habit of concentrating in great numbers in the growing bark. However, they are sometimes both numerous in and damaging to fruit and other trees. They may cause discoloration of the wood through which their burrows pass, the "blued" or stained areas exhibited by various timbers, when split, often being caused by them. Again, they may fill what would otherwise be valuable timber, so full of pin holes that it is worthless. Some of the species, instead of living upon wood or bark, derive their sustenance from a fungus which grows along the walls of their burrows, and which they introduce and propagate as carefully as the farmer does his grain. Whether or not the burrows are designedly utilized for fungus pastures, they furnish, especially after being vacated by the beetles, entrance for accidental germs of all sorts of ferments, rots and decay.

It seems that, in some cases, where the food supply is abundant and other conditions are congenial, the beetles, upon reaching maturity, do not go outside their burrows to seek new trees, but start new burrows off the old ones, and thus the work of destruction goes on with an acceleration exactly proportioned to the geometrical rate of increase of the insects. However, the fact that the fungus-feeding species are dependent on the normal development of their fungus pastures naturally limits their multiplication, and at the same time suggests effective remedial measures. The young larvae browse on the tender, newly-formed parts of the fungus, while the adults clip back the older and tougher threads. If, for any reason,

the pasturage is interrupted by a reduction in the number of beetles, or if conditions favor a specially exuberant growth of the fungus, there is great likelihood, according to Mr. H. G. Hubbard, that it will over-run and choke the burrows, at the same time overwhelming and suffocating the occupants. So perilous are the conditions under which these insects must propagate, that it is surmised that only under exceptional circumstances does it happen that more than one generation is produced in the same burrow. This is probably the reason why these little pests have never attracted much attention or become wholesale pests in an orchard. If the burrows are closed, the fungus may either fail, or it may over-master the panic-stricken beetles which cannot escape. Therefore, whitewashing or coating the trunks with thick, soapy preparations, or spraying oil emulsions into the burrows to kill the fungi, may all prove very effective measures. Driving wooden pegs or short wire plugs into the external openings of the burrows or pinholes will accomplish the same end. Or, perhaps, poles stuck in the ground will serve as traps and attract the beetles away from the living trees. Bisulfide of carbon may be injected into the holes and the openings then closed with a plaster of mud, putty or grafting wax. In case of severe attack, the trunks and larger branches might be protected by being wrapped with newspapers or old cloths, but for large scale treatment the orchardist will obviously have to depend largely upon keeping his trees in a healthy condition, as free as possible from mechanical injuries and abrasions, and such an operation as whitewashing.

Weakened and unhealthy trees are the ones apt to be attacked, just as is true in the case of the true bark beetles; so proper orchard hygiene, sufficient cultivation, good and abundant fertilization, and correct spraying will furnish the surest safeguards against attack. Where a very few trees are involved, it may be advisable to cut them down at once and burn, if the attack is serious. In case of specially threatening conditions for a whole orchard or neighborhood, should such ever develop, it would be advisable to add whitewashing or similar treatment to the best orchard hygiene; and, further, it might be worth while to girdle a few forest trees, if these were known to be preferred food plants, so as to weaken them and attract to them all the beetles in the neighborhood; after which, while inhabited by the insects, they could be cut down at the most advantageous date and burned.

Brief accounts of some of these pinhole borers affecting orchard trees follow:

BANDED PIN-HOLE BORER

Monarthrum fasciatum Say.

This little beetle is more of a timber pest than an orchard enemy, but a number of times it has been recorded as injuring apple and peach. Mr. G. C. Davis, in 1895 (Trans. Mich. Hort. Soc.) reported this species and the following one injuring peach, both having been previously recorded on apple. Prof. F. M. Webster also recorded it on peach in August, 1895 from Noble County, O. (Ohio Farmer, Aug. 22, 1895). Mr. R. D. Whitmarsh of this Station, under date of June 2d, 1910, speaking of a visit to the orchard of Mrs. T. S. Johnson, Port Clinton, O., says: "I found two peach trees in the orchard just south of the house very badly infested with beetles and, on examination, I found that the borer causing the destruction of the tree was neither *E. rugulosus* nor *P. liminaris*, but *Monarthrum fasciatum*. Mr. J. L. King, May 8, 1912, reports finding this species working on peach in the same orchard. He says: "The beetle was working in the green wood 5 feet above the ground. The burrow was started through a lenticel opening. A second specimen was taken May 20 in much the same environment as the first." Mr. King also enters the following note: "Oct. 14, 1912: In the branches of a dying cherry tree at Mr. Wright's (Lakeside, O.) I found a number of specimens of *M. fasciatum*. The beetles were in long burrows in the heartwood. I find that there is a slight tendency for these beetles to follow the annual rings in the formation of their burrows. As many as three and four beetles may be found in a single burrow. The work of this species is easily distinguished from that of *P. liminaris* and of *E. rugulosus* by the entrance hole and by the white wood-frass which is found at the mouth of the burrow. No eggs nor brood was found in any of the burrows opened." Mr. E. A. Schwartz noted in 1886 that "The main gallery runs in the solid wood concentric with the bark; while the secondary galleries branch off rectangularly from the main gallery and run upward or downward."* He also reported finding about 20 specimensof the beetle in a single gallery. Mr. H. G. Hubbard states that the egg-laying and feeding habits of this species are exactly the same as those of the next species treated. Besides feeding in apple, peach and cherry, Hopkins† lists it, from various authorities, infesting pine, white oak, black oak, basswood, beech and hemlock. He also gives the following dates for capture of adults: Feb. 20, March 2, April 14, 15, 17, 18, May 18, July 21,

Fig. 8. *Monarthrum fasciatum*, enlarged. After Hubbard, Bur. Ent., U. S. D. A., Bul. 7, New Series.

*Proc. Ento. Soc. of Wash. Vol. 1, P. 44.
†Bulletin 32, W. Va. Agr. Exp. Sta.

Aug. 6, 22, Sept. 3. Mr. Chas. Dury reports it as abundant at Cincinnati and gives the following dates of capture: May 7, July 13, Sept. 8, etc. An examination of these dates and our own records indicates the possibility of an early and a late brood, with great irregularity of development, or a single irregular generation may be the rule. Besides the Ohio localities given, there are some specimens in the Ohio State University collection, labelled Columbus, O., and others Defiance, O. In our collection is a number of specimens sent in by D. W. Morrow, Glenville, O., June 1, 1900, taken from maple; they were eating into the bark and wood.

Fig. 9. Gallery of *M. fasciatum*, much reduced in maple. After Hubbard. Bul. No. 7, New Series, Bur. Ent. U. S. D. A.

This has never been a serious orchard pest nor is it ever likely to become such; however, according to our observations and those of others, it may occasionally destroy one or more trees, usually weakened ones.

The beetle is slender and cylindrical in shape and about .10 inch or 2.4mm. long. The antennae are clubbed and in the male are fringed with very long hairs, while in the female, the hairs are few and short, and located on margin of club. The posterior declivity of the wing covers is hairy; and the front part of the wing covers is occupied by a yellow band, the posterior third being black. According to Leconte, it ranges from Lake Superior to Florida.

APPLE PIN-HOLE BORER, OR APPLE STAINER

Monarthrum mali Fitch.

This species is quite similar in habits and general appearance to the preceding species, but is somewhat smaller (2mm. or .08 inch long) and the male is provided with a long, terminal spine and a few hairs at end of club; spine is wanting on club of female. Fitch,* in his original treatment and description of the species, says: "Young thrifty trees, soon after putting forth their leaves in spring, suddenly withering, as though scorched by fire, the bark becoming loosened from the wood, and soon after numerous perforations like pin-holes appearing, penetrating through the bark into the wood, from each of which comes out a very small cylindrical beetle which is smooth, slender, black, sometimes dark chestnut red," etc.

He further states: "I only know this insect from specimens recently sent me from Middlefield, Mass., by Lawrence Smith, Esq., who writes me that he took them July 6, from the trunk of an apple

*Third Report on Insects of N. Y., 1856.

tree ten inches in diameter, which was numerously punctured from the surface of the ground to where the limbs commenced branching off, above which no traces of them were to be found. In another letter, he states that this insect was first noticed in his neighborhood two years ago, when several nursery trees were riddled by them. Nothing was seen of them last year; but they have reappeared the spring of the present year (1857) in greater abundance, and a number of trees have been ruined by them. I find a specimen of this same insect also in a collection sent me several years since from Ohio, by Dr. Robert H. Mack, of Parma." G. C. Davis recorded it on peach in Michigan (Trans. Hort. Soc.) in 1895. Hopkins* gives the following list of host plants; pine, white oak, black oak, jack oak, elm, beech, maple, chestnut, basswood, honey locust, yellow poplar (tulip), buckeye, Morello cherry, cedar and hemlock.

Fig. 10. *Monarthrum mali*, enlarged. After Hubbard, Bul. No. 7, N. S. Bur. Ent., U. S. D. A.

Mr. King took a specimen in Mrs. T. S. Johnson's orchard, Port Clinton, May 25, 1912, and in the State University collection are specimens taken at Columbus, O. Mr. Dury has taken it at Cincinnati, but says it is not common there.

The following is a resume of its feeding and breeding habits, extracted from the writings of H. G. Hubbard:† "The young are raised in separate pits or cradles, which they never leave until they reach the adult stage. The galleries, constructed by the female beetles, extend rather deeply into the wood, with their branches mostly in a horizontal plane. The mother beetle deposits her eggs singly in circular pits which she excavates in the gallery in two opposite series, parallel with the grain of the wood. The eggs are loosely packed in the pits with chips and material taken from the fungus bed, which she has previously prepared in the vicinity, and on which the ambrosia has begun to grow. The young larvae, as soon as they hatch, eat the fungus from the chips, and eject the refuse from their cradles. At first they lie curled up in the pit made by the mother, but as they grow larger they deepen their cradles with their own jaws, until, at full growth, they slightly exceed the length of the larva when fully extended. The larvae swallow the wood which they excavate, but do not digest it. It

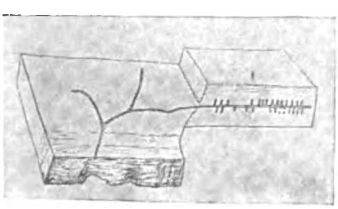


Fig. 11. Gallery of *M. mali*, much reduced. After Hubbard. Bul. No. 7, N. S. Bur. Ent., U. S. D. A.

*Bul. 31, W. Va., Agr. Exp. Sta.
†Bul. No. 7, N. S., Bur. Ent. U. S. D. A., P. 9.

passes through the intestines unchanged in cellular texture, but cemented into pellets by the excrement, and is stained a yellowish color. The pellets of excrement are not allowed to accumulate in their cradles, but are frequently ejected by them, and are removed and cast out of the mouth of the boring by the mother beetle. A portion of the excrement is evidently utilized to form the fungus garden bed. The mother beetle is constantly in attendance upon her young during the period of their development, and guards them with jealous care.

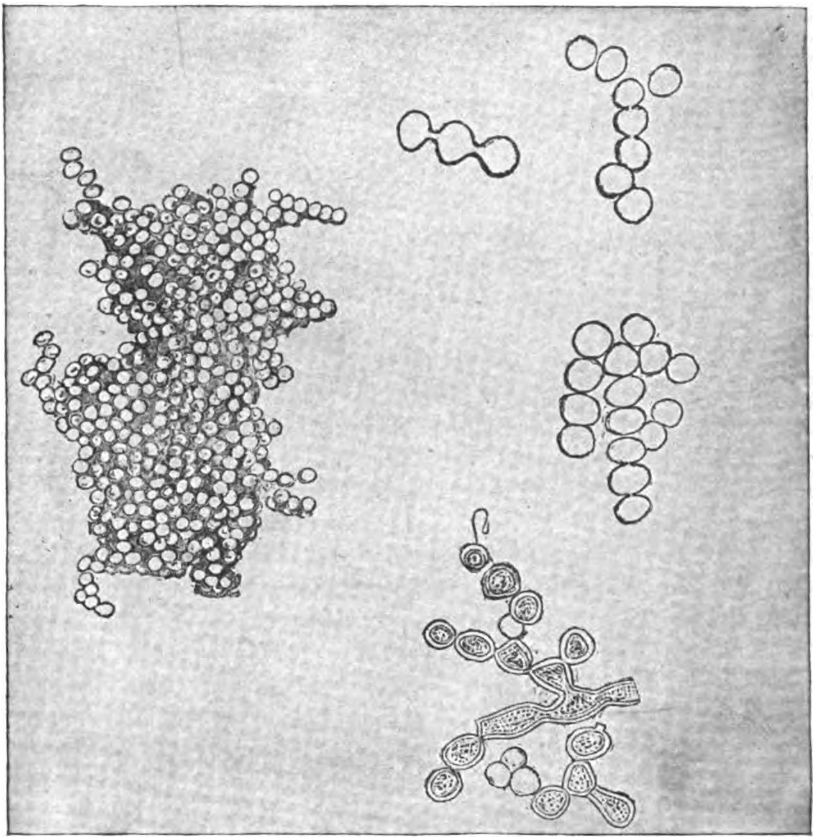


Fig. 12. Ambrosia of *M. mali*, greatly enlarged. After Hubbard. Bul. No. 7, N. S. Bur. Ent., U. S. D. A.

The mouth of each cradle is closed with a plug of the food fungus, and as fast as this is consumed it is renewed with fresh material. The larvae from time to time perforate this plug and clean out their cells, pushing out the pellets of excrement through the opening. The debris is promptly removed by the mother, and

the opening again sealed by ambrosia. The young transform to perfect beetles before leaving their cradles and merging into the galleries.

The Ambrosia of *Monathrum* is moniliform and resembles a mass of pearly beads. In its incipient stages, a formative stem is seen which has short joints that become globular conidia and break apart. Short chains of cells, sometimes showing branches, may often be separated from the mass. The base of the fungus mass is stained with a tinge of green, butthe stain in the wood is almost black.

Two species, *M. fasciatum* Say and *M. mali* Fitch are confined to the Atlantic forests, and range in latitude from Lake Superior to Florida. They have identical habits, and feed upon the same fungus. They are commonly associated in the same tree-trunk, not seldom occupying galleries having a common entrance hole. Both species are known to attack wine casks, but they probably breed only in dying trees.

Perhaps the most effective method of preventing injury to wine, cider and vinegar casks is to keep them in dark cellars or darkened rooms as the insects seem to shun such situations. Painting the casks with white paint, with Bordeaux mixture, with whitewash, or with Carbolineum would doubtless assist in repelling the beetles. They probably resort to casks only for the purpose of feeding, as no record has been made of their breeding in such situations. Staves, or wood intended for making barrels or other articles, if infested with these or other timber beetles in whatever stages of development, can be freed from living forms by subjecting the wood to live steam or dry heat for a few hours.

It is improbable that any of these insects would survive 150° Fahr. if continued for 2 or 3 hours.

The trees attacked include oak, hickory beech, maple, aspen, apple and orange, and the list might be extended to include other hardwood timber.

Hopkins gives the following dates for capture of adult beetles: Feb. 20, March 14 to 19, May 4, 8, 30, July 16, 20, 21, 24, 25, 29, 30, Aug. 4, 12, 22, Sept, 3, Dec. 6, Jan. 31. Pupae, eggs and larvae were found July 21. There may be one, two or more broods per year so far as can be inferred from these dates. The beetle ranges from Lake Superior to Florida according to Le Conte.

PEAR BLIGHT BEETLES

Xyleborus dispar Fabricius and *Xyleborus pyri* Peck.

Two other scolytids which may occur in Ohio but which, so far as we have been able to learn, have never been definitely recorded in the state, are *Xyleborus pyri* and *Xyleborus dispar.* The latter

species is an importation from Europe, pitchy brown to black in color, the wing covers inclining to reddish brown. The female is about one-eighth of an inch long, the male considerably smaller. It is known as the Pear Blight Beetle and is injurious to pear, apple, plum, cherry and several kinds of forest trees such as hemlock, beech and oak. It partially girdles young trees, sometimes before they leave the nursery, this causing the death of the upper parts. It tunnels into the trunks of older trees and hollows out the pith and centers of small twigs. The openings into the burrows are small and circular, as is usual with the shot-hole borers. The life cycle in America has not been very thoroughly worked out, but the data gathered indicate the probability of finding the adult beetles packed in the tunnels, end to end, forming a continuous line in the fall and winter months. The eggs for the autumn generation are probably laid in August and September, the larvae being found in the fall and winter, feeding together with the adults on a fungoid growth which lines the tunnels and which is carefully propagated under the intelligent supervision of the insects. The tunnel made by this borer is first toward the center, then a horizontal gallery is made running part way around the trunk or branch, and at right angles to this a large number of galleries are excavated, running up and down the stem. O. Schneider-Orelli* has traced out the life history in Europe and finds that in Switzerland the females migrate to new trees to found new colonies beginning as early as April 19, and may continue such activity throughout a period of two months, according to climatic conditions. Eggs were found May 10, the majority being laid in late May and ceasing wholly with the beginning of June. The number of eggs laid by a single female varied from 6 to 45; these are usually laid in clusters of six, chiefly at the junctions of the tunnel system, seldom being laid in the blind tunnels. The pupal stage

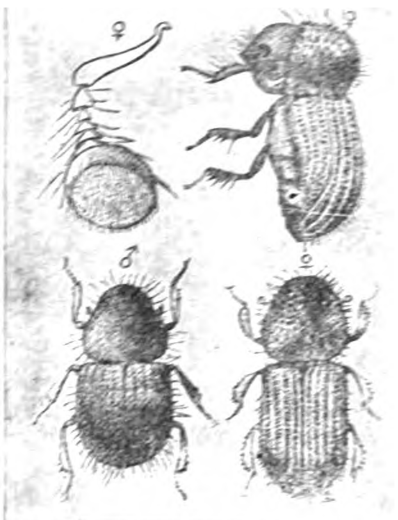


Fig. 13. *Xyleborus dispar:* **male and female imagoes, enlarged; antennae of female more enlarged. After Hubbard, Bul. No. 7, N. S. Bur. Ent., U. S. D. A.**

*Centralbl. Bakter., Paras. and Insekt., 2 Abt. XXXVIII, No. 1-6, 1913, pp. 25-110.

lasts from 10 to 14 days and the young beetles hibernate in the tunnels. According to these observations there is but one generation per year. A species of *Xyleborus*, probably this species, was received from Hudson, O., May 13, 1912. Badly infested trees should be cut and burned in the fall. Healthy trees, if threatened, should be kept thrifty and whitewashed, or kept covered with a carbolized soap paint to repel the beetles and prevent egg laying.

Xyleborus pyri has been recorded from West Virginia and probably occurs in Ohio. It may possibly be identical with *X. dispar*, and is sometimes found associated with it. It enters the green sapwood and heartwood of logs, stumps, injured living trees, and probably healthy trees as well. In food habits, life history and economy, it may be assumed to closely parallel *X. dispar*. Hopkins records for W. Va., adults May 8, 9; larvae, June 1; eggs, May 8, 9.

TWIG BORERS

All of the species previously treated belong in the family Scolytidae, but two other small beetles of another family, with boring habits, are occasionally encountered and require mention. These belong in the family *Bostrychidae*, or Powder Post Beetles.

APPLE TWIG BORER

Amphicerus bicaudatus Say.

This is cousiderably larger than any other species treated in this bulletin ranging from one-fourth to over one-third of an inch in length. It is dark chestnut brown, or almost black in color, and the thorax is roughened in front with minute elevated points. The male also has two little horns projecting forward on the thorax, one on each side, and a tubercle, or thorn-like projection at the hindermost extremity of each wing cover. The adult beetle bores into small apple twigs in early spring, entering close beside a bud and excavating a channel down the pith which may be several inches long. Both sexes enter twigs in this manner, and sometimes may be found in such burrows in winter as well as during the summer. Twigs of pears and cherries, also grape canes are entered and killed in this manner. During the summer, the beetles generally leave these feeding burrows and deposit their eggs in the dead and dying roots of greenbriar or catbriar (*Smilax*) or in the dead shoots of grape.

Twigs containing the beetles or their burrows should be pruned out and burned and, if the beetles are abundant, destroy all catbriar plants and wild grapes to be found in the neighborhood. Some specimens in the Station collection were sent in from Boggs, O., April 5, 1897. They were said to be abundant at that place and time. Some

more recent reports of damage may have been occasioned by this species, but we have no record, confirmed by specimens, except as above stated.

RED-SHOULDERED SINOXYLON

Sinoxylon basilare Say.

This blackish beetle is closely related to the preceding, but is considerably smaller, being about one-fifth of an inch long and has a large reddish spot at the base of each wing cover. The thorax is furnished with elevated points and short spines in front. The wing covers make such a sudden declivity downward and backward that they appear to be cut off obliquely inward behind, forming a V with the point headward; each side of the V is armed with three teeth. It injures the stems of grapes by boring into them, also the trunks and branches of peach and apple trees. The grub which develops in dead twigs is much wrinkled, yellowish-white and has the anterior segments much swollen and enlarged. The pale- yellowish pupa is formed within the burrow. Infested canes and twigs should be pruned out and burned and the trunks of threatened trees protected as from other small borers. One record from Wooster, Ohio, March 3, 1899, reared in insectary from hickory twigs. We have also received it from Perry, O., July 8, 1910, in peach, it being reported as seriously injurious.

THE COB-ROT OF CORN

OHIO

Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., NOVEMBER, 1913.

BULLETIN 265

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 265 NOVEMBER, 1913

THE COB-ROT OF CORN*

By E. G. ARZBERGER

INTRODUCTION

The fungus organism which, in part, initiated the work on this problem was first sent to the Experiment Station by W. J. Wheeler, of Paulding, Ohio, April 12, 1911. He had noted that the cob tissue of some of his stored seed corn, crop of 1910, had become somewhat abnormal; this was partly due to the activity of a fungus which was subsequently identified as belonging to the genus *Coniosporium*.

Some preliminary observations were made on this fungus during the year after it was found. During the fall and winter of 1911-12 the fungus again appeared abundantly on the husked corn. In April, 1912, more extensive observations and investigations were begun, the details of which are set forth in this report.

The chief object of this investigation was to determine whether the fungus in question, *Coniosporium Gecevi* Bubak, found on the ears of field corn is a true parasite or only a saprophyte.

The literature regarding this fungus is not very extensive, and the greater part of it consists of mere mycological descriptions. Saccardo, including those in his 17th volume, has described 82 species of Coniosporium. Some of the descriptions are detailed enough and state whether the species are parasitic or saprophytic, while others are recorded rather incompletely. The nature of the greater number can be judged from the dead or decaying wood or plant tissue upon which the fungus had been found.

Of the 82 species given, 57 are saprophytic, 10 parasitic and 15 are questionable, regarding their nature. These may be saprophytes or facilitative parasites.

*In the fall of 1911 there was prevalent over Ohio a disease or affection of corn which had not previously been observed on so large a scale. The trouble was manifested in a softening and decay of the cob, rendering the grain unmerchantable. The outbreak was so general that great anxiety was felt lest a serious disease of this most important cereal had made its appearance, and in response to request of leading grain dealers and others an emergency appropriation was authorized by the Emergency Board for the study of the outbreak by the Botanical Department of the Experiment Station. This work was assigned by the Station Botanist to Mr. E. G. Arzberger, Assistant Botanist, an abstract of whose report upon it is given in the following pages. A. D. Selby, Botanist.

Lindau, in Rabenhorst's Kryptogamic Flora, describes 40 species, of which 37 are obligate saprophytes, and 3 are parasitic; some of these are questionable, however, regarding their parasitic nature. One species described may be classed as a facilitative parasite.

Jaap and Bubak haxe recently described three other species of Coniosporium, all of which are saprophytic. The greater number of the above have been found in Europe. Spegazzini, in his list of Mycetes Argentinensis of South America, reports four new species, all of which are saprophytic.

If access could be had to the proper herbarium material, it would probably be found that *Coniosporium Gecevi*, described in 1911, had already been described as some other form in America. However, from the most authentic mycological descriptions one may note the general saprophytic nature of this genus. In Rabenhorst's Kryptogamic Flora, Lindau makes this general statement about the entire genus: "The development of this fungus, especially the nature and formation of the conidia, is still unknown, and requires elucidation through cultural examinations. The *greatest number live* as *obligate saprophytes*, yet not without exception, as is shown in *Coniosporium arundis*, which, in its mycelial stage, is found in the living tissue of its host plant."

Bubak,[1] of Tabor, Bohemia, describes in Centrb. f. Bak. u. Infekk. 31: 500-502, 1911, a new species of Coniosporium, found on the cob of corn ears. He sets forth a somewhat detailed description of the fungus and states that the fungus is not a parasite but only a saprophyte which covers the glumes and parts of the kernels, darkens them and can render the corn material slightly less valuable. He proposes the name *Coniosporium Gecevi* Bubak n. sp.

To be positively certain whether the species of Coniosporium, that is associated with our corn, is the same as Bubak had reported from Bulgaria, some specimens were sent to him on February 17, 1912, asking him to compare them with his native material. Similar specimens were also sent to Sydow and Lindau at Berlin and to Saccardo at Padua, Italy. These men were requested to identify the fungus sent, and also to state whether they regarded it as a parasite or a saprophyte.

During the following March replies were received from all four men. Lindau classes it in the genus Epicoccum and says: "It might be possible that this fungus grows first as a parasite and fruits as a saprohytic growth. However, investigation regarding this phase will elucidate."

[1]Einige interessante Pflanzenkrankheiten aus Bulgarien. Von Prof. Dr. Fr. Bubak (Tabor, Bohmen) und Dr. P. Kosaroff (Sofia, Bulgarien). (Referent Dr. Fr. Bubak.) Erster Teil. (Several interesting Plant Diseases from Bulgaria by Dr. Fr. Bubak (Tabor Bohemia) and Dr. P. Kosaroff (Sofia, Bulgaria). First part.) Centrb. f. Bakt. u Infekk. 31: 495-502, plates 2.

Sydow says, "I have found that it belongs to the genus Coniosporium, but I am unable to identify it with any known species so that I believe that it is a new species. I cannot decide the question whether the fungus is a parasite or only a saprophyte, but I am inclined to think that it is a saprophyte."

Bubak states that the fungus sent to him is identical with the one he has described. He sent some of his original specimens, of which the spore measurements and other characteristics agree well with our native material. He says in his letter: "I first received this fungus from Bulgaria in the winter and therefore could not decide with certainty whether it is a parasite or a saprohyte."

Saccardo in his reply states that the fungus is a new species of Coniosporium, but later corroborates the view held by Bubak. He makes no assertion regarding its parasitic or saprophytic nature. These statements show that it is not always an easy matter to decide whether a fungus organism is parasitic or saprophytic.

OBSERVATIONS MADE IN 1911

During the summer of 1911 cultures were made from the various tissues of the ear upon which the Coniosporium is found. These were developed at different intervals during the summer season until inoculations were made in August on a number of corn plants grown in the pathologist's garden. As a result the fungus was found on the check plants as well as those that had been inoculated. Because of too limited knowledge regarding the fungus no exact data could be obtained. Besides this, many unfavorable environmental conditions, not anticipated, led to indeterminate results.

A number of days were spent during November and December examining the husked corn on the Station's fields in regard to this rot. Similar data were obtained from fields in the northwestern and southwestern parts of the State. The results of this work are summarized in Tables I and II. Some observations were also made on normal growing corn during the summer of 1911. No evidence could be obtained of the fungus as being associated, as a pathogenic organism, with the living corn plants. Yet but little assurance was placed in this, for very little was known regarding the nature of the fungus and how it behaves in the plant before it becomes conspicuous enough to be noted by the observer.

The first instance where the fungus was found was on ears of corn, the stalks of which had been cut about 2 weeks before. The tips of undeveloped ears were first affected and as the cob tissue lost its cell sap and the living processes of the cells ceased, the fungus would continue its growth into these parts.

Observations were made during November, December and on through April, 1912. In these observations the Coniosporium was found developed on the shanks, and infrequently some of the inner sheathing leaves of ears were covered with the mycelium and spores of the fungus. No other part of the corn plant could be found which was affected by the Coniosporium; and furthermore, no other species of plants associated with the corn were found affected by this fungus. It was assumed that Coniosporium might live on other plants during the spring and early summer months, which habit would help bridge it over until the corn is in a condition to be affected by it.

Only one specimen of another plant was found that was affected by Coniosporium, that being a head of barley which was dead and dry, having been eaten off by some insect. None could be found after a diligent search on the living barley plants. Here may be noted its saprophytic nature. During May and June a careful study was made of the young corn plants and of grasses and weeds growing with them. The only fungi found were *Pleospora* and *Epicoccum neglectum* on the the dead portions of clover leaves and on some of the dead portions of orchard grass and timothy. The Epicoccum also appears as a saprophyte on old, dead corn ears, leaves and stalks during the early spring after an abundant rainfall. It is of but little economic importance because it attacks those decaying parts which are of no practical value to the farmer.

In noting abnormal stages of young corn plants, the reddened condition, especially of those grown on clover or grass sod, was frequently observed. This, however, was generally due to the injury done by grubs, wire worms and other insects. The wounds serve as portals of entry for soil bacteria, which find their way into the vascular bundles, inhibiting the living processes of the plants and discolored, dwarfed plants are produced. Often, when the physical and biological conditions of the soil are unfavorable, the lower part of the stem of the young plant becomes affected with fungi and bacteria. These will affect the stem and roots and produce sick plants. The real causes for the abnormal conditions produced, subsequent to the dying off of the primary portion of the stem, are rather difficult to ascertain because of the many factors that enter in. All subsequent investigations were carried on in experimenting to determine whether the Coniosporium is a parasite or saprophyte.

METHODS OF WORK

The cultures were all grown on nutrient glucose agar in petri dishes. Fresh cultures were made continually in large quantities during the summer. During the hot weather of the

months of July and August only a few spores were developed by the fungus, but ample growth of mycelium was formed on the culture media. Later, however, the cultures were placed in the ice box, which furnished sufficient coolness for the development of spores on the mycelium. In cooler weather the mycelium grew profusely, forming an abundance of spores within a few days.

Sterile methods, that were best suited, were employed in making inoculations. All wounds were made with a sterile scalpel or needle on tissues that were sterile or had been made sterile by washing with bichloride of mercury. After the fungus had been inoculated into the tissue of the plant the wound was covered over by sterilized paper to keep out all organisms and to let only the inoculated organism be present in the tissue that was treated.

Besides the pure cultures on nutrient media, dilution cultures with distilled water were made and used; cob material affected with Coniosporium was also used. Inoculations were made from day to day when the weather permitted, and usually in the afternoon, when moisture conditions did not interfere with the inoculation process. All plants were labeled with tags dated and numbered consecutively.

Between July 30 and October 17, 1912, 276 inoculations of corn plants were made, laboratory numbers 1,056 to 1,331, inclusive, the work being done on 29 different dates and the inoculating material being placed in the nodes, internodes, roots, brace roots, sheath leaves, shanks, ears, silk and top leaves. Besides these, 40 to 50 inoculations were made on very young corn plants in greenhouse, garden and laboratory; 258 of these inoculations were made with Coniosporium cultures. These inoculations were examined at different dates until November, but no infections of Coniosporium were found from any of them.

On September 19th inoculations of 9 plants, Nos. 1251 to 1259, inclusive, were made of a mixed culture of two or more fungi that were found associated with decaying ears in last year's investigation of husked corn in the field. One fungus is a Diplodia and the other a dark colored organism, which with the Diplodia forms a grayish colored mass. The dark mycelium never has produced any fruiting bodies of any sort. It seems to live symbiotically with the Diplodia which I assume, from a limited knowledge of it, prepares conditions for the growth of the dark mycelial organism. The Diplodia, however, carries out the parasite's nature and brings about the results as found.

Examinations of the inoculated plants were begun on September 12 and contiuued until December, but no evidence was found of any infection by Coniosporium due to these inoculations.

On October 9th a somewhat superficial examination was made of the plants first inoculated with the Diplodia fungus. All nine ears of these plants at this time were beginning to show infection with the fungus. The inoculated ears were covered again with sterilized paper and were not examined again until in November. All the other corn plants, excluding the above nine, in this group, were inoculated with Coniosporium, but no infection took place.

The last examination of these plants was made on November 6th. The corn had at this time all been killed by freezing and the stalks had nearly dried out. The same ears on the plants, numbered from 1254 to 1259, inclusive, showed a good growth of the fungus inoculated in all parts of the ear. Some ears were more affected than others. At this time the white mycelium, apparently of Diplodia, covered considerable of the kernels. The early growth and action of the fungus on the kernels and cob is very similar to that of the Diplodia. Dark mycelial masses are produced that resemble very much the immature fruiting bodies of Diplodia. The dark, heavy-walled mycelium is very different from that of Diplodia. It seems that the Diplodia-like organism acts parasitically and after it has done its work this black colored fungus develops with it and grows as a saprophyte. The relationship of these two fungi appears somewhat complicated and involves a problem requiring further investigation.

LABORATORY EXPERIMENTS

One of the first experiments in this connection was carried on in the laboratory in the following manner: Growing ears of corn, in which all tissues were living, excepting a few portions of the sheathing leaves, were taken from healthy plants in the field. A certain number of these were placed in wire baskets and sterilized in the autoclave for one hour at 15 pounds steam pressure for two successive days. This was done to make sure that every particle of corn tissue was killed, and that nothing placed thereupon could grow or live as a parasitic organism. After their removal from the autoclave, under the best sterile conditions afforded, the ears were variously inoculated with fresh and pure cultures of Coniosporium. The inoculated specimens were then placed in large, sterilized battery jars, kept moist with sterilized filter paper; these in turn were covered with large sterilized bell jars. A sufficient amount of moisture was furnished by the sterile water poured upon the filter paper and into the bottom of the jars.

The same day similar inoculations were made on ears of living corn in the field and on ears brought into the laboratory, which were placed as checks in battery jars under bell jars without cooking.

After eight days the ears which had been cooked in the autoclave and subsequently inoculated with the pure cultures presented an abundant growth of mycelium and spores. The fungus had penetrated through the cob tissue, passing out and surrounding the kernels and filling up the cavities between the kernels and rows.

The living specimens under the bell jars, and those in the field which were inoculated the same day, showed no development on the living kernels and cob tissue, when also examined eight days after their inoculation. Plenty of moisture was present for the living and dead ears in both sets of experiments in the laboratory, a factor which was somewhat deficient with specimens in the field. However, this was not a general missing factor, inasmuch as the fungus did not develop on and in the living tissue when it had an abundance of moisture. Apparently the living protoplast of the kernels and cob tissue presents unfavorable conditions for the development of this fungus when placed there in its most active stage of growth. Numerous similar examples are also afforded by the inoculations made on the living tissues of the corn in the field during the summer. Examination and reexamination again and again showed that no infection had taken place in the live tissue; whereas, in the dead tissue, killed around the wound by the method of inoculation, there developed a good growth of the fungus. If enough moisture was present a good growth of mycelium would be produced on the tissue as it gradually died back from the wound. In this dead tissue, and especially in that of the cob, the fungus produced its normal amount of spores, which were viable and would again produce the fungus when placed on culture media.

Results quite similar to the preceding were also obtained by using last year's ears that had been naturally affected with the Coniosporium in the field. These were placed in a moist chamber, after washing off with bichloride of mercury (2 parts to 1,000 of water) some of the superficial spores of other fungi. After ten days or more the fungus had developed in the cob and about the kernels, giving the entire ear a somewhat grayish appearance, providing other fungi did not predominate in growth. However, it is very difficult to get a pure growth of Coniosporium under these conditions, because other forms, like Fusarium, Rhizopus, Penicillium, Aspergillus and Cephalothecium, will finally develop on the unsterilized material, thus making it difficult with so many of these other organisms to determine just how much Coniosporium would develop after having naturally become affected, and subsequently placed under these somewhat abnormal conditions.

Further evidence, showing that Coniosporium grows as a saprophyte, is deduced from the following experiment: Pure cultures of the fungus were placed on sterilized cellulose prepared from good filter paper. This had been digested with concentrated hydrochloric acid and subsequently washed free from the acid and sterilized in small Erlenmeyer flasks, from which it was poured into large petri dishes. Whenever the cellulose was too dry, sterile distilled water was added to make it loose as well as moist.

At ordinary room temperature, 16 to 18° C., the fungus started its growth quite readily and after 20 days the surface of the cellulose in the 100 mm. petri dishes was literally overgrown with the mycelium of the fungus. Later the mycelium penetrated through the entire mass of cellulose as well as covering the surface, which was black with spores.

With no other material than pure water and cellulose on which to develop, the readiness and length of time that Coniosporium will grow on this, certainly sets forth some evidence that it does not require living protoplasm in or on which to find the necessary nutriment for its development. Very few, if any, of the parasitic fungi can be made to develop to any great extent on pure water and cellulose alone. The fact that it can obtain food elements from these two compounds shows that it is not concerned at all during its living processes with living protoplasm or living cells to serve it as a host.

This fungus can easily be grown on other forms of cellulose. Pieces of pith, taken from the stems of elder and corn stalks, were placed in large test tubes with a small amount of distilled water. After sterilizing these in the autoclave the pith was inoculated with pure cultures of Coniosporium. A sufficient amount of water was left in the bottom of the tube to keep the pith moist. Growth of the fungus took place immediately and within eight days a great many of the pieces were penetrated and covered by the gray colored fungus. In this case it is clearly shown how the fungus affects the thin-walled parenchymatous cells, rather than the sclerenchyma cells that make up a part of the vascular bundles, the cortex of the corn stalk and a large portion of the hard material of the corn cob.

Furthermore, the readiness with which this fungus develops on the various culture media by transferring methods tends toward showing that this fungus presents no parasitic tendencies. Fungi that are known to be true obligate parasites are not easily changed in their nature from a parasite growing on living plants to a saprophyte growing on artificially prepared culture media. It was found that *Coniosporium Gecevi* developed on all the media that

were tried. It developed more readily and more luxuriantly on media that contained an abundance of grape sugar and some form of nitrogen. The following media, titrated to +1 to +1.5, were used and growth was obtained on all of them; nutrient glucose agar, corn meal agar, lima bean agar, plum decoction agar, Riedemeister's and Dr. Moore's synthetic media and sterilized wheat bread, besides the cellulose and pith already mentioned.

The fact that the Coniosporium grows so readily on some of the media and also that it grows on all the media, no special method or medium being required to make it grow as a saprophyte, is evidence of its saprophyte nature. On the other hand, obligate parasites, such as Rusts, Smuts, Helminthosporiums, and Peronosporas, are grown only with great difficulty on artificial media, because of the selective properties of the organisms and their obstinate nature in being changed to saprophytes. These obligate parasites affecting the corn plant have been found by investigators to offer many difficulties in growing them artificially.

Another experiment was performed with small corn plants growing in the greenhouse. The plants were from 10 to 15 days old, 3 to 4 inches high and growing vigorously, thus possessing a considerable amount of meristematic tissue which is frequently more susceptible to infection by fungus organisms. The soil covering the roots and lower part of the stem was removed, pure cultures of Coniosporium were abundantly applied, and the soil was replaced. These plants were in no way affected or inhibited in their growth when compared with the check plants growing along with them. A similar experiment was carried out on plants grown in the garden. No symptoms that the plants were being affected in any respect could be noted on any of these.

The results from these experiments further support the conclusion that the Coniosporium organism is not a parasite, but merely a saprophyte.

Besides the experimental work in the laboratory, greenhouse and garden plots, observations were made on the corn in various parts of the State and in local fields of farms adjoining the Station. Of the many thousands of corn plants thus observed and studied no plant was found where Coniosporium was active as a pathogenic organism. Again, if this organism had been the cause of serious disease heretofore, it is presumed that it would not have escaped the detection of mycologists and plant pathologists during the past years. It certainly could not have developed *de novo* or through some mutating process during the past few years.

Judging from the extent to which this fungus is found, it seems probable that it has been indigenous with the corn in this country and only the favorable weather conditions brought about its abundance in the crop of 1911.

ECONOMIC SIGNIFICANCE OF CONIOSPORIUM

Since this fungus, as ascertained from investigational evidence, cannot be considered as the cause of disease of the living corn plant, it has, nevertheless, an economic importance, for it does render the kernels less valuable, as do the mucors, penicillium, aspergillus and other similar forms. It is true that the mycelium penetrates the various cob tissues and the lower portion of the kernel, such as the funiculus. Besides the basal portion, it may cover over as much as the lower half of the kernel. But it cannot be maintained that Coniosporium injures the young plant or embroyo in the kernel. The conditions which are favorable for the development of the fungus have previously been unfavorable to the living processes in the young plant, which is dead before the fungus begins its saprophytic action on that portion of the kernel.

The injury done by the Coniosporium, aside from that done to the cob tissue, is relatively small, comparing ear with ear of those affected with other fungi which destroy the entire kernel and render its food content almost valueless.

In regard to its effect on the feeding value of the corn, farmers who fed their cattle with corn affected by Coniosporium claim that no abnormal effects could be noted on animals fed with such corn. Several farmers stated that they fattened stock on just such corn. It is difficult to have corn affected only with the Coniosporium, and when symptoms of disease in the animal did occur, it may have been brought about by other forms of fungi that are known to be the cause of diseases in animals to which corn is fed.

The effect of cob-rot on the ears of corn after maturity would appear analogous to certain timber-rot fungi which attack the heart or other portions of the tree trunk, while not attacking the living portions of the tree, although the heartwood be still enclosed within the cylinder of the living layer. The analogy here suggested is that the economic value of the corn attacked by cob-rot is impaired, and in even greater proportion than the economic value of the timber destroyed by timber-rots. While we can not call such timber-rots of pine, oak, etc., diseases of the living oak or pine trees, we recognize their economic significance as timber-rots. In a similar sense the cob-rot will continue to be recognized as an impairment of the matured corn ears whenever prevalent.

OTHER FUNGUS DISEASES OF CORN

A diseased condition of the corn was first noted about August 14th in the variety plots and later in the ensilage fields of the Station. The most apparent symptoms in the leaves are quite like those caused by the early stages of rust infections. At first the spots are quite small and about a millimeter in diameter. Later these may enlarge to circular spots a centimeter across and frequently several of the small spots merge and form one large spot. These regions in the leaf are quite translucent and when all the leaves are affected it gives the plant a somewhat mottled appearance when observed by transmitted light. Photographs of the affected leaves will hardly present the spots in a surface view that will set forth the actual and essential features. The spots will after a time become brown, dry and hard. The pressed specimens will show this. From the incomplete study made, it appears that the mesophyl of the leaf is most affected but the vascular system is quite resistant and therefore very few leaves were found collapsed from the lack of water. It is difficult to find the early stages of this infection. A microscopic examination will reveal spores of rust bacteria and large spherical bodies and swarm-spores of this fungus which Barrett calls *Physoderma zeae maydis*. It is still a question whether this fungus in its swarm-spore stage does the entire injury, for the many cultures, made from the diseased parts, revealed two kinds of bacteria, one forming a white colony and the other a yellow. No growth of the fungus was secured although about 300 plates of cultures were made on nutrient glucose agar. Inoculations were made with the two bacterial forms but no symptoms were obtained. I am of the opinion that the bacteria are only secondary intruders.

A considerable number of leaves were pressed and preserved in good condition but it is quite difficult to find many of the resting spores in the dry material. The best and only method for the study of this is with the fresh material.

This fungus trouble was reported by Barrett[2] at the Science Meeting held at Cleveland last December. The illustrative material displayed by him resembles the material I found. I sent him some specimens and regarding them he says: "As far as I am able to make out they bear the same organism as found here and that I described at the Cleveland meeting."

Although the symptoms of the disease are very conspicuous, yet little is known about the real cause as to how they are produced. Therefore, careful isolations and inoculations must be made before much can be definitely stated about it.

[2] *Physoderma zeae maydis* Shaw, in Illinois, by J. T. Barrett.

TABLE I: Fungi found at husking, Oct. 20-30, 1911, on corn of different varieties.

Variety of corn	Total No. of ears per shock	No. affected with Coniosporium	Per cent	No affected with Diplodia	Per cent	No. affected with Fusarium	Per cent	Total percent affected
1. U. S. No. 78	186	46	24.7	0	0	1	0.6	25.3
2. Funk's Yellow Dent..	154	44	28.6	2	1.3	0	0	29.9
3. " " " ..	141	44	31.2	0	0	0	0	31.2
4. " " " ..	148	29	19.6	2	1.3	0	0	20.9
5. Stickney's Flint......	170	147	80.6	2	1.2	0	0	81.8
6. " "	202	176	87.1	0	0	0	0	87.1
7. " "	148	138	93.2	0	0	0	0	93.2
8. Check Clarage........	175	87	49.7	3	1.7	1	0.6	52.0
9. " "	177	53	29.8	2	1.1	0	0	30.9
10. Clarage x White Cap.	204	69	33.8	3	1.5	0.	0	35.3
11. " " " ...	172	47	27.3	0	0	2	1.2	28.5
12. Cranz's White Cap....	153	78	50.9	0	0	0	0	50.9
13. " " "	149	41	27.5	0	0	1	0.7	28.2
14. Check Clarage........	165	57	34.5	0	0	1	0.7	35.2
15. Silver King...........	180	27	15.0	1	0.55	0	0	15.5
16. " "	175	68	39.0	1	0.6	0	0	39.6
17. Untested Seed...	123	14	11.4	0	0	0	0	11.4
18. " "	151	26	17.2	2	1.3	0	0	18.5
19. " "	189	74	39.1	0	0	5	2.6	41.7
20. Reid Zehring..........	164	33	20.1	0	0	0	0	20.1
21. " "	154	39	25.3	0	0	0	0	25.3
22. Strain No. 84.........	132	36	27.4	1	0.8	0	0	28.2
23. " " 84..	136	32	23.5	1	0.8	0	0	24.3
24. " " 84.........	141	22	15.6	0	0	1	0.7	16.3
25. " " 84.........	132	26	19.7	2	1.5	0	0	21.2
Average...................			34.87		1.13		1.0	35.15

TABLE II. Fungi found at husking in November, 1911, on corn planted at different dates.

Time of planting	Total No. of ears per shock	No. of Unaffected ears	Percent	No. affected with Coniosporium	Percent	No. affected with Diplodia	Percent	No. affected with Fusarium	Percent	Total percent affected
1. April 29, 1911.	184	150	81.5	31	16.8	3	1.7	0	0.	18.5
2. " " " .	159	126	79.4	29	18.2	3	1.9	1	0.5	20.6
3. " " " .	141	109	77.4	30	21.2	0	...	2	1.4	22.6
4. May 7, 1911....	170	128	75.3	37	21.8	3	1.7	2	1.2	20.6
5. " " "	181	148	81.8	33	18.2	0	0.	0	0.	18.2
6. May 16, 1911..	180	144	80.+	33	18.3	1	.55	2	1.1	18.96
7. " " " ..	145	125	83.5	20	14.4	.	....	3	2.06	16.46
8. May 26, 1911..	143	129	83.3	22	15.3	2	1.4	.	....	16.7
9. " " " ...	159	128	80.5	29	18.2	.	....	2	1.3	19.5
10. June 6, 1911 ..	158	131	83.0	26	16.4	1	.6	.	....	17.0
11. " " " ...	135	100	74.1	35	25.9	.	....	.	....	25.9
12. " " " ...	175	154	88.1	19	10.8	.	....	2	1.1	11.9

Table II gives the percentage of the different fungi found at husking on corn planted on different dates in 1911. No Coniosporium was found affecting the corn before or during the time of cutting. With the exception of Diplodia and Fusarium, all Coniosporium developed on the ears in the shock during the moist weather.

There were only 3 shocks of the different plantings, hence no larger number of observations could be obtained. But from the limited observations that could be made on the small field, the data

show that there is no difference in the total amounts of fungi occurring on the corn planted at different times in spring. The Coniosporium was found just as abundantly on the early as on the late plantings. The weather conditions are the chief factors in determining the amount of Coniosporium that will develop on ears of corn.

TABLE III: Fungi found at husking, Oct. 24 to Nov. 14, 1912 on corn of different varieties.

Variety of corn	Total No. of ears per shock	No. affected with Coniosporium	Percent	No. affected with Diplodia	Percent	No. affected with Fusarium	Percent	Total percent affected
1. Boone Co. White......	130	1	.76	.	...	1	.76	1.5
2. " " "	145	2	1.40	.	...	.	....	1.4
3. " " "	152	..	.....	.	...	1	.6	.6
4. " " "	136	..	.....	1	.7	.	....	.7
5. " " "	131	..	.....	.	...	1	.76	.8
6. " " "	111	..	.....	1	.9	.	....	.9
7. Clarage..............	157	5	3.20	.	...	.	....	3.2
8. "	140	3	2.10	.	...	1	.7	2.8
9. "	141	4	2.80	.	...	3	2.1	4.9
10. U. S. No. 182..........	154	..	.....	.	...	.	....	0.
11. " " " "	126	..	.....	.	...	.	....	0.
12. " " " "	148	..	.....	.	...	.	....	0.
13. Cook's Original.......	145	..	.....	.	...	.	....	0.
14. " "	138	..	.....	.	...	.	....	0.
15. " "	132	..	.....	.	...	.	....	0.
16. Cook's No. 75.........	187	9	4.80	.	...	1	.5	5.3
17. Check Clarage........	160	6	3.80	2	1.3	.	....	5.1
18. Early Leaming (Frost)	181	10	5.50	.	...	5	2.7	8.2
19. Early Leaming.......	180	31	10.70	1	.6	.	....	11.3
20. Untested Seed........	256	6	2.30	.	...	5	1.9	4.2
21. " "	226	3	1.30	.	...	4	1.8	3.1
22. " "	203	4	1.90	.	...	3	1.4	3.3
23. " "	197	9	4.60	.	...	3	1.5	6.1
24. Check Clarage........	113	11	9.80	.	...	.	....	9.8
25. " "	129	4	3.10	.	...	2	1.6	4.7
26. " "	171	7	4.10	.	...	7	4.1	8.2
27. " "	144	4	2.80	.	...	6	4.1	6.9
28. " "	121	..	.....	.	...	1	.8	.8
29. " "	110	8	7.30	.	...	2	1.8	9.1
30. Tested Seed..........	180	7	3.90	1	.5+	4	2.2	6.6
31. " "	181	6	3.30	.	...	1	.5+	3.8
32. " "	52	12	23.00	.	...	2	3.8	26.8
33. Untested Seed........	55	5	9.09	.	...	4	7.2	16.29
34. Dark Co. Mammoth...	83	15	18.07	.	...	.	....	18.07
35. " " " ...	90	14	15.50	.	...	2	2.2	17.7
36. " " " ...	71	16	22.50	.	...	.	....	22.5
37. Dark Co. Mammoth...	81	10	12.30	2	2.5	.	....	14.8
38. " " " ...	221	3	1.30	.	...	4	1.8	3.1
39. Leaming.............	78	20	25.60	.	...	2	2.5	28.1
40. "	195	10	5.20	.	...	3	1.5	6.6
41. "	108	17	15.70	1	.9	2	1.8	18.4
42. Clarage new..........	126	2	1.60	.	...	.	....	1.6
43. " "	158	13	8.20	.	...	.	....	8.2
44. " "	201	9	4.40	.	...	.	....	4.4
45. " "	232	11	5.70	.	...	2	.8	6.5
46. Clarage old (short ear)	132	10	7.60	.	...	.	....	7.6
47. " " " "	201	6	2.90	.	...	5	2.4	5.3
48. " " " "	156	9	5.70	.	...	2	1.3	7.0
49. " " " "	223	16	7.20	.	...	9	4.0	11.2
50. " " " "	187	6	3.20	.	...	2	1.0	4.2
51. " " " "	230	8	3.50	.	...	6	2.6	6.1
52. " " " "	151	14	9.20	.	...	.	....	9.2
53. " " " "	182	14	7.60	1	.5	7	3.8	11.9
54. " " " "	216	8	3.70	.	...	4	1.8	5.5
Average..............			6.90		.98		2.07	7.79

The corn in shocks numbered 10-15 inclusive in Table III was very green when it was cut and contained considerable moisture in

the stalks and sheathing leaves, while all the cob tissue and kernels contained considerable cell sap. This greenness or presence of much living tissue accounts for the ears not being affected by any fungi. Not all the shocks of this variety were examined and there may have been some that were affected with Diplodia.

The percents of corn found affected with Coniosporium in 1912 range from 0 to 26.6, which is relatively lower than that of the crop of 1911, where the range found is 11.4 to 93.2 percent. The average of the total affected plants, as found in 1912, is 6.9 percent, while that of 1911 is 34.8 percent, showing that the crop was considerably more affected in 1911 than in 1912.

In Table III the data numbered from 32-37 were taken from husked shocks in a part of the field where grub worms had done considerable injury during the entire summer and the stalks, with partly developed ears, died very readily and the ears soon afforded enough dead tissues for the Coniosporium to begin its growth. Following this, on Nos. 38-54, the percents are somewhat lower, indicating a better and more normal growth of corn in the same rows of the field, but there was inhibition of growth, apparently by external factors.

SUMMARY

Of the many thousand living corn plants examined none were found that were injured or diseased with *Coniosporium Gecevi*.

Inoculation experiments were carried on from July 30th to October 15th, 1912, a period of 78 days, during which time all stages of corn plants were utilized for the many different methods of inoculations that were used to duplicate or carry out such as might occur under natural conditions.

No infections were obtained on the living corn plants from the 276 inoculations made in the field. Besides these the 40 to 50 inoculations made on very young corn in greenhouse, garden and laboratory presented no evidence of infections.

Eighteen inoculations, made with an unknown fungus or fungi (probably Diplodia and another organism), produced good infections and diseased ears. Further detailed data is needed on these organisms, before more definite statements can be made.

Field and laboratory tests indicate that *Coniosporium Gecevi* develops and acts as an obligate saprophyte, and therefore cannot be considered as the cause of a disease.

Coniosporium has an economic significance in that it destroys the cob tissue as a saprophyte; its effect on the kernels is rather limited when compared with the injury of Diplodia, Fusarium and other fungi.

LABOR COST OF PRODUCING CORN IN OHIO

OHIO Agricultural Experiment Station

IN COOPERATION WITH THE OFFICE OF FARM MANAGEMENT
U. S. DEPARTMENT OF AGRICULTURE

WOOSTER, OHIO, U. S. A., DECEMBER, 1913

BULLETIN 266

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

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[3]In cooperation with Bureau of Plant Industry, U. S. Department of Agriculture.
[4]In cooperation with Boys' Industrial School. [5]In cooperation with Ohio State Reformatory.

CONTENTS

ILLUSTRATIONS

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 266 DECEMBER, 1914

LABOR COST OF PRODUCING CORN IN OHIO

A study conducted jointly by the Office of Farm Management, Bureau of Plant Industry, United States Department of Agriculture, and the Department of Cooperation, Ohio Agricultural Experiment Station

By L. H. GODDARD AND W. L. ELSER

During the decade 1900-1909, the average annual production of corn in Ohio was 3,014,607 bushels.* On account of the importance of this crop and the extent to which it is grown throughout the state, it is essential that we know what it costs to produce it, and what are the profits resulting from its production. Owing to the many factors and uncertainties in its production, it is quite difficult to arrive at an accurate cost, but on the basis of nearly 200 fields with a total of more than 2,000 acres, representing 23 counties of the state and with the records extending over a period of seven years, fairly accurate conclusions, at least regarding the labor cost, may be drawn.

In determining the cost of production it is essential that all the labor, whether man or animal, and whether performed by the operator and his family or by hired help, be taken into consideration. While this is perhaps the most important factor in the cost of production, yet it is only one of many. The following outline shows the factors that go to make up the total cost of production.

(1) Labor { Man { Hired / Operator and his family; Beast }

(2) Land rental—or the interest and taxes on the amount invested in the land

(3) Machine rental—or the machinery cost of implements used in producing a given commodity—consisting of:

Annual depreciation—determined from the inventories.

Repairs { Labor—obtained from the labor reports. / Cash—obtained from the financial accounts. }

Interest on the average capital invested in the implement.

Taxes and insurance on the implement.

*From the reports of the Ohio State Board of Agriculture.

(4) **Supplies**—such as seed; twine; fuel for shredding, silo filling, etc.
(5) **Cash rental of machines and crew**—such as $1.25 per hour for silo filling.
(6) **Fertility**—a proportion of the value of manure, fertilizer or lime applied.
(7) **Interest**—on the cost until the enterprise yields a return.
(8) **Overhead cash expense**—items which cannot be charged to any particular enterprise, but which are prorated among all the enterprises at the end of the year. In many cases a number of small amounts, each of which could be charged directly to some enterprise, have been reported under one head such as, "blacksmithing," "hardware," etc. When they were reported in this manner it was necessary to charge the amount to "General Farm." Other examples of general farm expense are: admission to corn shows and county or state fairs; farm papers; telephone rent; stationery, etc.
(9) **Insurance**—on growing crops against plant diseases, insects, hailstorms and other weather conditions.

The first three items in the foregoing should be found in every crop enterprise, while the fourth and eighth are very common. The item "storage charge" or the rental on the buildings required to store the crop, has not been included in the foregoing outline, for the reason that it is not considered an item in the actual cost of production, but is more properly an item that should be charged against the storage of the crop after it has been harvested, and depends somewhat on the management of the farm and the disposition made of the crop. Since the labor required to produce the crop is of such importance and is so frequently overlooked or underestimated in determining the cost of crop production, an attempt is made in the following pages to discuss some phases of that factor alone.

DEVELOPMENT OF THE INVESTIGATION

The work of collecting the data, on which this bulletin is based, had its conception with the Agricultural Students' Union. Since 1905 the investigation has been prosecuted by the Department of Cooperation of the Ohio Experiment Station, and since 1907 it has been conducted in cooperation with the Office of Farm Management, U. S. Department of Agriculture. In 1905 two cooperators were keeping the labor records on their farms and their first records were of such a nature that it was possible to use them in the preparation of this bulletin. These two men are still keeping records. The number of cooperators keeping similar records has varied from year to year. From the map (Figure 1) on page 87 it will be seen that the various sections of the State have been fairly well represented.

Since July, 1909, the work has been under the supervision of Mr. W. L. Elser. Prior to that date it was in charge of Mr. M. O. Bugby of this Department, to whom the writers wish to acknowledge the great value of the records maintained by him from the beginning of the work in 1905 until he turned it over to others.

Acknowledgements are also due to Messrs. H. M. Dixon and M. R. Cooper, formerly of this Department, and to Messrs. Van Over, Brown and Musser of this Department, for the valuable service they have rendered in connection with this work.

The writers also wish to express their appreciation of the hearty cooperation the many farmers have shown by the excellent condition in which they sent in their records.

FIG. I.
MAP SHOWING
COUNTIES IN WHICH FARMS
UNDER CONSIDERATION
ARE LOCATED

Daily Time Sheet of..Farm.

In cooperation with
O. A. E. S. and U. S. D. A.
In Farm Management Investigations.

Make all records on day work is done.

Day of week.. **Date**...

Man Hours	Horse No.	Horse Hours	Field	Kind of Work—*Give kind and size of implement used and area covered or amount of work done. When an operation is finished, so state.*
4.30				
5.00				
5.30				
6.00				
6.30				
7.00				
7.30				
8.00				
8.30				
9.00				
9.30				
10.00				
10.30				
11.00				
11 30				
12.00				
12.30				
1.00				
1.30				
2.00				
2.30				
3.00				
3.30				
4.00				
4.30				
5.00				
5.30				
6.00				
6.30				
7.00				
7.30				

Total Hours ....Workman.

Wage ....

No. Meals ....

Give below kind, amount and value of seed sown, fertilizer used, manure hauled, material used in any operation (such as building fence, etc.) and crop yields (both grain and roughage). Also give source of material, area or portion of field affected and any notes regarding weather, crops or stock, which may be of interest or value.

....

....

Made out by..

Fig. 2. Form used in collecting the data.

METHOD OF COLLECTING THE DATA

The data have been collected quite largely by correspondence, supplemented by visits for the purpose of taking inventories, measuring fields, etc. Figure 2 shows a time sheet such as is used in obtaining the daily labor reports. These sheets are bound in convenient pads and are furnished each cooperator free of charge. In return he makes out the records for each day in duplicate, sending the original to the Experiment Station at the end of the week and retaining the duplicate for his future reference.

From this figure it is manifest that all the labor performed on the farm during the day is accounted for. This bulletin, therefore, is the first of a series, others of which are now in process of preparation, concerning the various farm crops and enterprises, which were embodied on the farms under consideration. This form of labor record is not recommended as being the only workable method or the form best adapted for use by those wishing to keep their own records. It has, however, proved to be a very satisfactory form for correspondence use from an investigational standpoint, though even here it is not infallible. In many cases, for instance, it has been impossible to obtain the actual number of acres covered in any one operation, such as harrowing or discing. However, this is readily overcome by dividing the total time for all the operations of a similar nature by the acreage of the field. This gives the time per acre for any class of operations, and it is this division which later on gives rise to the fractions of hours other than those ordinarily reported on the daily time sheets. This division also gives rise to combinations of operations which have arbitrarily been termed "Fertilization," "Care of Seed," "Preparation of Seed Bed," "Planting," "Cultivating," "Harvesting," "Miscellaneous Labor," and "General Farm Labor." In referring to these combinations they will hereafter be designated as "Partial Items."

In this publication the term "Fertilization" is used to include all the time of applying manure, mixing and applying fertilizers, and applying lime. Though it is undoubtedly incorrect to charge all of the time of applying manures etc., to the first crop, yet owing to the lack of an authoritative decision in this country regarding the residual effect of manures etc., we have so charged the time for applying in each of the succeeding tables and charts. "Care of Seed" refers to the time required for selecting, storing, testing, shelling, etc., of the seed corn used. The "Preparation of Seed Bed," "Planting," "Cultivating" and "Harvesting," each includes all of the various operations necessary for that particular "Partial Item." "Miscellaneous Labor" includes all labor on corn that does

not regularly fall in any of the foregoing partial items. Inspecting the crop, looking up help for husking, etc., would be examples of what should come in this class. The "General Farm Labor" is labor performed during the year which cannot be charged directly to any particular enterprise at the time the work is done, but must be carried until the end of the year and then prorated or distributed among the various enterprises in proportion to the amount of work done on each. Examples of such labor are: attending public sales, institutes or fairs; farm correspondence and records; mowing weeds along fences and roadsides; cleaning up buildings, etc.

The amount of time devoted to "Fertilization," "Care of Seed," "Miscellaneous and General Farm Labor" varies greatly with individual men and even on different fields operated by the same man. Since this variation is due more largely to individuality than to any other influence these partial items have not been shown in Tables XI, XII and XIV on pages 101, 106, 112, nor in Figures 4, 5, 7, 8, 9, 10 and 11, but the amounts given for the totals include these partial items as well as those shown by those tables and charts.

HOURS VS. DOLLARS AND CENTS

In the tables presented in this Bulletin it will be noted that the cost is referred to more frequently in terms of hours than of dollars and cents, for the reason that the cost of labor varies in different sections and under different conditions. The following, and many similar questions, which form the basis of future study, must be answered before we can attempt to put a valuation on the hours of labor that would be comparable in various sections. What is the value of the board, the laundry work done, or the "horse-keep" furnished the laborer who lives in the home of the operator, or the value of the house and garden, wood, meat, milk, etc., furnished the laborer who boards himself? Does the rate of wage include these? Is the operator's wage the same as that of the hired man? How much does it cost to keep a horse per year, and what is the rate per hour of horse labor? Even with this information it is doubtful if the labor cost, expressed in dollars and cents, has as much significance as when expressed in the terms of man and horse hours. However, in some cases it has been necessary to express the cost of labor in dollars and cents, and in such cases the rates of sixteen cents per hour for man labor and eight cents per hour for horse labor have been assumed. While these rates have been assumed in order to make the records comparable, still they can scarcely be considered as being unjust. Table I, published in the December 1910 Bulletin of the Ohio State Board of Agriculture, shows the average wages paid farm hands in 1,056 or more than three-fourths the townships in Ohio.

TABLE I. Rate of wages paid farm laborers. Gathered and returned by official correspondents of the Ohio Department of Agriculture.

Counties	No. townships reported	What is average wage paid to farm hands			
		By day with board	By day without board	By month with board	By month without board
Adams	11	$1.00	$1.25	$17.55	$22.90
Allen	12	1.23	1.63	21.57	30.25
Ashland	10	1.45	1.71	23.46	30.00
Ashtabula	18	1.34	1.68	22.53	30.43
Athens	8	1.08	1.49	20.29	29.20
Auglaize	12	1.40	1.69	21.89	30.38
Belmont	14	1.12	1.48	20.10	27.60
Brown	10	1.00	1.45	20.64	26.78
Butler	11	1.09	1.53	21.64	30.00
Carroll	10	1.23	1.68	22.73	30.00
Champaign	10	1.28	1.60	22.30	28.33
Clark	5	1.12	1.45	22.20	30.00
Clermont	9	1.08	1.43	19.27	24.88
Clinton	8	1.07	1.53	19.25	25.71
Columbiana	14	1.28	1.73	22.53	36.42
Coshocton	14	1.19	1.65	21.31	30.61
Crawford	16	1.46	1.95	23.10	33.08
Cuyahoga	9	1.38	1.89	23.80	37.29
Darke	14	1.26	1.68	21.27	31.33
Defiance	8	1.22	1.64	22.75	29.60
Delaware	15	1.31	1.72	19.69	27.93
*Erie	10	1.40	1.67	23.91	33.55
*Fairfield	16	1.25	1.65	21.89	30.43
Fayette	7	.86	1.14	19.94	24.71
Franklin	17	1.15	1.51	22.10	30.81
Fulton	8	1.53	1.93	24.38	33.80
Gallia	8	.94	1.22	19.45	25.33
Geauga	14	1.37	1.85	24.60	34.31
Greene	10	1.12	1.45	21.56	32.33
Guernsey	14	1.08	1.47	19.75	28.37
Hamilton	9	1.19	1.58	21.43	31.29
Hancock	16	1.31	1.76	22.06	31.40
Hardin	12	1.27	1.67	21.77	30.73
Harrison	14	1.16	1.60	21.23	30.78
Henry	13	1.30	1.64	22.29	32.09
*Highland	20	1.03	1.34	19.43	26.45
Hocking	7	1.03	1.38	21.60	29.00
Holmes	9	1.23	1.58	21.80	30.83
Huron	16	1.55	2.02	23.47	32.33
Jackson	7	.96	1.27	18.00	25.40
Jefferson	13	1.16	1.59	20.77	28.46
Knox	17	1.29	1.68	21.94	30.38
Lake	7	1.38	1.93	22.28	36.00
Lawrence	9	.83	1.11	19.90	26.22
*Licking	28	1.20	1.63	20.70	28.33
Logan	16	1.32	1.55	20.22	25.00
Lorain	15	1.34	2.00	25.42	35.86
Lucas	10	1.35	1.75	22.90	34.44
Madison	9	1.02	1.29	21.90	28.66
Mahoning	10	1.23	1.70	24.55	33.71
Marion	13	1.48	2.02	23.60	32.14
Medina	11	1.48	1.75	23.82	32.44
Meigs	10	.90	1.25	18.78	29.71
Mercer	12	1.38	1.77	24.80	31.81
Miami	9	1.36	1.72	21.72	26.28
Monroe	15	1.06	1.46	16.29	24.78
Montgomery	11	1.18	1.53	21.31	30.29
*Morgan	17	1.04	1.48	19.50	24.32
*Morrow	18	1.33	1.80	22.72	29.61
Muskingum	22	1.13	1.57	19.96	29.27
*Noble	16	1.20	1.37	18.76	29.17
Ottawa	7	1.35	1.80	23.58	35.00
Paulding	9	1.32	1.92	21.80	32.87
Perry	13	1.13	1.69	24.46	33.73
Pickaway	14	.91	1.20	20.73	27.70
Pike	8	.92	1.14	19.50	26.87
Portage	13	1.48	1.80	24.60	36.50
Preble	12	1.31	1.65	24.36	29.40

TABLE I—Continued Rate of wages paid farm laborers. Gathered and returned by official correspondents of the Ohio Department of Agriculture.

Counties	No. townships reported	What is average wage paid to farm hands			
		By day with board	By day without board	By month with board	By month without board
Putnam	9	$1.36	$1.72	$21.65	$28.20
Richland	15	1.45	1.87	22.00	31.45
Ross	11	.96	1.23	19.50	27.32
Sandusky	9	1.39	1.80	25.70	37.00
Scioto	15	1.00	1.30	20.14	29.20
Seneca	12	1.46	1.39	24.25	34.30
Shelby	9	1.33	1.72	22.12	29.17
Stark	14	1.27	1.77	23.43	36.22
Summit	16	1.50	1.81	22.81	34.09
Trumbull	19	1.24	1.68	23.63	33.06
Tuscarawas	17	1.11	1.49	22.45	31.30
Union	14	1.30	1.66	21.61	29.73
Van Wert	8	1.33	1.64	22.50	31.57
Vinton	10	.88	1.29	20.66	29.80
Warren	9	1.11	1.58	21.50	29.50
Washington	19	.96	1.36	18.62	25.79

*Counties with townships having more than one reporter

In the spring of 1913 inquiries regarding the various rates of wages paid for labor of different classes were sent to the mayors of Ohio municipalities having a population between 2,500 and 10,000. Table II gives the results of these inquiries.

TABLE II. Showing rates of wage and days worked per year for different classes of workmen in 34 Ohio municipalities with an average population of 5,831.

Municipality number	Population	Common laborer: Wage per day Min.	Common laborer: Wage per day Max.	Common laborer: Hours worked per day	Common laborer: Days worked per year	Common laborer with team: Wage per day Min.	Common laborer with team: Wage per day Max.	Common laborer with team: Hours worked per day	Common laborer with team: Days worked per year	Carpenter: Wage per day Min.	Carpenter: Wage per day Max.	Carpenter: Hours worked per day	Carpenter: Days worked per yr.	Stone mason: Wage per day Min.	Stone mason: Wage per day Max.	Stone mason: Hours worked per day	Stone mason: Days worked per yr.
1	6,795	$1.75	$2 00	10	190	$5.00	$6.00	10	175	$2.00	$3 50	10	225	$3.50	$4.50	10	185
2	5,209	2.00	2.50	10	200	5.00	6.00	10	200	2.50	3.50	10	250	4.50	5.00	9	140
3	5,222	1.75	2.00	10	230	3.50	4.00	10	230	3.50	....	10	200	....	....	..	...
4	6,621	1.50	2.00	10	300	4 00	4.50	10	220	2.50	3.50	10	250	4.00	5.00	10	200
5	9,603	1 75	....	9	190	5.00	....	9	140	3 50	....	8	240	5.00		8	100
6	3,028	2.00	5.00	8	300	4.50	....	8	300	3.00	3.00	8	260	5.00	5.00	8	156
7	4,665	1.75	2.25	10	260	3.50	4.00	10	260	3.00	....	10	230	5.00	....	10	200
8	3,187	1.75	2.50	10	250	3.50	4 00	10	250	2.50	3.00	9	280	4.00	5.00	9	250
9	9,597	1.75	2.00	10	230	2.00	2.00	10	230	3.00	3.50	8	230	5.00	5.50	8	230
10	7,214	....	2.00	10	250	....	4.50	10	250	2.75	3.20	10	250	3.50	6.00	10	250
11	5,560	1.25	1.50	9	260	3.00	3.50	9	260	2.50	2.75	9	208	3.50	4.00	9	156
12	3,736	1.35	2.00	10	300	5 00	5.50	9	300	4.00	....	8	300	....	4.00	8	300
13	6,237	1.75	2.50	10	200	3.50	4.00	10	200	1.75	3.50	10	250	3.50	4.00	10	160
14	4,488	....	1.75	10	203	....	4.50	10	222	....	....	..	...	....	....	.	...
15	7,185	1.75	2 00	10	210	4.00	4.00	10	200	3.00	3 00	10	200	4.00	4.00	10	200
16	4,850	1 50	2.00	10	260	4.00	4.50	10	260	2.50	3.50	10	260	3.50	4.00	10	260
17	9,133	1.50	2.00	10	208	4.50	5.00	9	208	3.20	3.40	8	208	....	5.00	8	208
18	2,734	1 50	2.00	10	240	4.00	5.00	10	240	2.50	3 00	10	275	3.00	5.00	10	275
19	4,271	1.50	2 00	10	270	3.50	4.00	10	200	2.25	3.25	10	300	2.25	3.25	10	250
20	2,759	1 75	2.25	10	250	4.00	4.50	10	180	2.50	3.00	10	200	5.00	6.00	10	100
21	9,087	1.50	2.00	10	290	3.50	5.00	10	270	2.25	3.50	8	270	....	5.00	8	150
22	8,542	1.60	2.00	10	250	....	4.50	10	200	2.50	3 50	10	150	3.00	4 50	10	150
23	8,361	1.75	2.00	9	300	....	4.95	9	250	3.25	3.25	8	250	....	5.20	8	225
24	4,365	1.50	2.00	10	200	5.00	5.50	10	200	3.00	3.50	10	225	4.00	4.50	8	200
25	4,023	1.25	1.50	9	200	4.50	....	9	200	2.50	3.50	8	200	2.50	3.50	8	175
26	8,943	1.75	2.25	9	300	4.50	5.00	9	200	3.25	3.40	9	200	4 80	4 80	8	200
27	4,903	1.75	2.50	10	300	5.00	....	10	250	2.50	3.00	10	250	4.00	5.00	9	200
28	6,607	1.75	2.00	10	200	3.75	4.50	10	200	2.50	3.00	10	250	4.00	5.50	10	200
29	5,732	1.35	1.75	10	280	3.25	3.75	10	260	1.75	2.25	10	256	3.50	4.00	10	220
30	6,122	1.75	2.00	10	230	3.50	4.00	10	156	2.50	3.00	10	156	....	5.00	10	156
31	4,751	1.50	2.00	10	300	4.50	5.00	9	300	2.50	3.50	9	300	4.00	4.00	9	150
32	7,157	1.50	2.50	9	300	3.50	5 00	9	300	2.50	4.00	9	300	2.50	5.00	10	156
33	3,073	1.50	2.00	10	250	4.00	4.50	10	212	2.25	3.00	9	225	....	....	..	...
34	4,491	1.50	2.25	10	200	3.50	4.00	10	200	3.00	4.50	10	225	4.00	5.00	10	175
Total....	198,251	$51 80	$71.00	332	8,391	$120.00	$135.20	329	7,723	$88.70	$95.50	308	7,873	$100.55	$136.25	285	5,977
Average.	5,831	1.62	2.15	9.76	246.79	4.00	4.51	9.68	227.15	2.69	3.29	9.33	238.58	3.87	4.70	9.19	192.81
Rate per hour......		.166	.22	......	....	.413	.466	......	....	.29	.353	......	....	.405	.511	......	......
Av. daily wage		$1.89				$4.25				$2 97				$4.31			
Av. rate per hour...		.194				.439				.318				.469			

TABLE II.—Continued. Showing rates of wage and days worked per year for different classes of workmen in 34 Ohio municipalities with an average population of 5,831.

Municipality number	Population	Brick mason: Wage per day, Min.	Brick mason: Wage per day, Max.	Brick mason: Hours worked per day	Brick mason: Days worked per year	Painter: Wage per day, Min.	Painter: Wage per day, Max.	Painter: Hours worked per day	Painter: Days worked per year	Plumber: Wage per day, Min.	Plumber: Wage per day, Max.	Plumber: Hours worked per day	Plumber: Days worked per year
1	6,795	$5.00	$5.00	10	180	$2.00	$3.50	10	200	$5.00	$5.00	10	225
2	5,209	4.90	5.40	9	200	2.50	3.00	10	200	4.00	5.00	10	250
3	5,222	....	....	..	...	....	....	..	...	....	....	..	...
4	6,621	4.00	5.00	10	200	2.50	3.20	10	220	2.70	3.50	9	300
5	9,603	5.00	....	8	140	2.75	....	8	100	3.50	....	9	240
6	3,028	5.00	5.00	8	182	3.20	3.20	8	208	4.00	4.00	8	234
7	4,665	5.00	....	10	200	3.00	....	10	230	5.00	....	10	260
8	3,187	4.00	5.00	9	250	3.00	3.50	10	280	3.50	5.00	10	300
9	9,597	5.00	5.50	8	230	3.00	3.50	8	230	4.00	6.00	10	300
10	7,214	3.50	6.00	10	250	2.50	3.00	10	250	4.50	4.50	10	250
11	5,560	5.00	6.00	9	156	2.00	3.00	9	156	....	....	..	...
12	3,736	....	5.20	8	300	....	3.60	8	300	....	4.50	8	300
13	6,237	2.70	5.60	9	200	2.00	3.00	10	180	2.50	5.00	10	250
14	4,488	....	....	..	...	....	....	..	...	....	....	..	...
15	7,185	4.00	4.00	10	200	3.00	3.00	10	200	4.00	4.00	10	200
16	4,850	5.00	6.00	10	260	2.00	2.50	10	260	3.00	3.59	10	260
17	9,133	....	4.80	8	208	....	3.60	8	208	....	4.00	8	234
18	2,734	3.00	5.00	10	275	2.50	3.00	10	250	2.50	3.50	10	250
19	4,271	3.50	6.00	10	200	2.25	3.00	10	275	3.50	5.00	10	300
20	2,759	5.00	6.00	10	130	2.00	3.00	10	120	3.50	4.00	10	250
21	9,067	....	6.00	8	150	2.50	3.50	9	180	2.00	4.00	9	270
22	8,542	4.50	5.60	10	150	2.50	3.50	10	150	5.00	6.00	10	250
23	8,361	....	5.20	8	225	3.00	3.00	9	225	....	4.50	9	250
24	4,365	4.00	4.50	8	200	2.00	2.50	8	225	3.00	5.00	9	300
25	4,023	3.50	4.50	8	175	2.00	3.00	9	125	4.50	5.50	8	125
26	8,943	5.00	5.00	8	200	3.00	3.15	9	200	3.60	3.60	8	250
27	4,903	4.00	5.00	9	200	3.00	3.50	10	200	4.50	....	10	300
28	6,607	6.00	6.50	10	200	2.50	3.00	10	225	3.50	4.00	10	275
29	5,732	4.00	4.80	8	230	2.00	2.25	10	250	3.00	3.50	10	300
30	6,122	....	5.00	10	156	2.00	2.50	10	156	4.00	5.00	10	234
31	4,751	4.50	4.50	8	150	2.50	3.00	9	150	3.00	3.50	9	300
32	7,157	2.50	6.00	10	156	2.50	3.50	9	260	3.50	4.00	10	300
33	8,073	4.00	5.00	8	212	2.25	3.00	10	225	2.50	3.50	10	237
34	4,491	4.00	5.00	10	175	2.00	3.00	10	240	2.50	4.00	10	275
Total....	198,251	$115.60	$158.10	289	6,340	$73.95	$93.00	301	6,678	$99.80	$122.60	294	8,069
Average.	5,831	4.28	5.27	9.03	198.12	2.46	3.10	9.41	208.69	3.56	4.38	9.48	260.29
Rate per hour......		.474	.584	......	....	.261	.329	......	....	.378	.462	......	....
Av. daily wage.....		$4.80				$2.78				$3.97			
Av. rate per hour...		.532				.295				.419			

CLASSIFICATION OF THE RECORDS

In getting together the individual records of fields of corn and combining them, they naturally fall into certain groups or classes. One of the first classifications necessary to make is based on the general method by which the corn crop is harvested. The following outline shows the general methods adopted for this classification, and Tables III, IV, V and VI respectively, give the data by counties classified in that manner.

Grain harvested:—All the hours of labor reported. May include any combination of the following special methods of harvesting, with their attendant operations:

- Cut by hand
- Cut by machine
- Husked by hand—either from shock or standing stalk
- Husked by machine
- Fodder shredded.

Hogged off:—

Siloed:—Cut in the field either by hand or by machine.

Contract labor additional:—A part or all of the labor, especially in harvesting, done at a contract price and the hours of such labor not reported.

TABLE III. Labor required when grain is harvested.

County	Number of fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre	
			Man	Horse	Man	Horse
Allen	10	112.97	6,493.25	6.910 50	57.48	61.17
Ashtabula	1	4.21	273.44	267 22	64.95	63.47
Athens	1	2.83	213.75	160.00	75.53	56.54
Belmont	3	31.53	2,673.77	1,984.89	84.80	62.95
Coshocton	7	88.21	7,037 50	6,845.50	79 78	77.60
Crawford	11	115.27	5,667.25	5,546.50	49.16	48.12
Geauga	6	23.89	1,524.75	1,442.75	63.82	60.39
Greene	2	7.47	307 50	304.75	41.16	40.80
Hardin	7	76.37	3.103.32	4,151.24	40 64	54.36
Harrison	2	13.61	971.00	759.50	71.34	55.80
Holmes	12	133.28	7,633.49	9,065 33	57.27	68.02
Huron	8	96.10	4,755 19	5,966.65	49 48	62.09
Licking	3	29.56	1,437 25	1,616.00	48.62	54.67
Lorain	2	7.37	632.50	646 50	85.82	87.72
Madison	4	122.81	4.686.50	5,261.25	38.16	42.84
Meigs	6	8.85	863.75	710.75	97.60	80.31
Pickaway	6	202.34	8,380 81	8,923.76	41.42	44.10
Preble	11	252.53	7,406.50	13,989 00	29.33	55 40
Putnam	2	20.66	1,058.00	1 029.00	51.21	49.81
Seneca	1	12.01	660.75	514.25	55 02	42.82
Warren	3	39.33	1,723.75	1,584.50	43.83	40.29
Total	108	1,401.20	67,504 02	77,679.84	.....	.....
Average	...	12.97	....	......	48.18	55.44

TABLE IV. Labor required when corn is hogged off.

County	Number of fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre	
			Man	Horse	Man	Horse
Crawford	2	18.07	416.75	732.00	23.06	40.51
Hardin	2	10.92	170.75	342.75	15.64	31.39
Holmes	4	22.89	693.65	1,137.52	30.30	49.70
Madison	3	20.67	577.50	962.25	27.94	46.55
Pickaway	2	25.06	537.34	1,010.20	21.44	40.31
Preble	3	13.87	277.00	515.00	19.97	37.13
Warren	1	6.02	74.50	143.00	12.38	23.75
Total	17	117.50	2,747.49	4,842.72	.....	...
Average	..	6.91	....	....	23.38	41.21

TABLE V. Labor required when corn is siloed.

County	Number of fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre	
			Man	Horse	Man	Horse
Allen	2	23.47	1,735.00	2,056.25	73.92	87.61
Ashtabula	2	10.59	580.86	647.69	54.85	61.16
Belmont	1	7.72	433.75	568.75	56.18	73.67
Geauga	4	29.06	1,769.00	2,089.50	60.87	71.90
Hardin	2	15.75	726.18	1,048.26	46.11	66.56
Harrison	1	10.70	433.25	431.25	40.49	40.30
Seneca	4	18.49	946.25	1,091.50	51.18	59.03
Total	16	115.78	6,624.29	7,933.20	.....	.....
Average	..	7.24	....	....	57.21	68.52

TABLE VI. Labor required when there is contract labor additional.

County	Number fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre		Total value of contract labor	Value of contract labor per acre
			Man	Horse	Man	Horse		
Adams	4	66.71	2,850.75	3,557.25	42.73	53.32	$113.89	$1.71
Allen	2	51.59	3,351.75	3,770.25	64.97	73.08	42.87	.83
Athens	5	10.04	656.00	774.25	65.34	77.13	21.91	2.18
Belmont	1	10.28	635.25	597.50	61.79	58.12	16.75	1.63
Clinton	1	32.00	1,118.50	2,002.00	34.95	62.56	12.60	.39
Geauga	1	6.52	318.50	330.75	48.86	50.74	4.50	69
Greene	2	48.37	1,421.25	1,852.75	29.38	38.30	111.48	2.30
Hardin	3	58.19	2,482.00	3,458.50	42.65	59.43	48.18	83
Holmes	2	34.28	1,554.57	2,734.96	45.35	79.78	44.10	1.29
Huron	3	62.00	3,607.21	3,904.57	58.18	62.98	38.76	63
Madison	8	199.96	7,887.25	9,692.25	39.44	48.47	297.70	1.49
Pickaway	2	76.57	3,060.39	3,923.86	39.97	51.25	81.96	1.07
Preble	1	17.71	357.50	817.00	20.19	46.13	34.40	1.94
Seneca	1	13.61	938.75	723.50	68.98	53.16	4.20	.31
Total	36	687.83	30,239.67	38,139.39	.....	.....	$873.30	..
Average	..	19.11	....	....	43.96	55.45	... ..	$1.27

TABLE VII. Recapitulation of Tables III, IV, V and VI.

Table	Number of fields	Total acreage of fields	Average size of fields	Total hours of labor		Hours of labor per acre		Horse hours used per hour of man labor
				Man	Horse	Man	Horse	
Table III..	108	1,401.20	12.97	67,504.02	77,679.84	48.18	55.44	1.15
Table IV..	17	117.50	6.91	2,747.49	4,842.72	23.38	41.21	1.76
Table V...	16	115.78	7.24	6,624.29	7,933.20	57.21	68.52	1.20
Table VI*.	36	687.83	19.11	30,239.67	38,139.39	43.96	55.45	1.26

*$1.27 per acre additional for contract labor.

Fig. 3. Some methods of harvesting corn.

While one would hardly be justified in combining the totals of these various methods and deducing therefrom an average labor cost of producing the corn crop, it is a significant fact that the average of all of these fields, regardless of the method of harvesting, is 46.12 man hours and 55.37 horse hours per acre, with 1.20 horse

hours per hour of man labor, which averages are not materially different from those shown in Table III. However, the data for plotting the charts referred to in this Bulletin, Figures 4, 5, 7, 8, 9, 10 and 11, were secured from Table III.

If the rates of man and horse labor (16c and 8c respectively), previously mentioned, be used in connection with the average hours per acre (48.18 man hours and 55.44 horse hours) as shown in Table III, the average cost of labor only, on the 108 fields of corn is found to be $12.14 per acre.

From Table VIII the labor cost of producing an acre of corn may be determined when varying rates of man and horse labor are used in connection with the average hours shown in Table III. This cost per acre, including both man and horse labor at any given rate for each, is determined by finding the rate of man labor on the left, and following that rate across horizontally until we reach the column which has the selected horse rate at the top. For example, if the rates of 16c per hour for man and 8c per hour for horse labor are used, the rate of 16c is found on the left, and following this line across until the column headed 8c is reached, it is found that the cost of man and horse labor combined is $12.14.

TABLE VIII: Showing total labor cost per acre at varying prices per hour for man and horse labor: based on 48.18 man hours and 55.44 horse hours per acre, as per Table III.

Man hour prices	Horse hour prices											
	5c	6c	7c	8c	9c	10c	11c	12c	13c	14c	15c	16c
10c	$7.59	$8.14	$8.70	$9.25	$9.81	$10.36	$10.92	$11.47	$12.03	$12.58	$13.13	$13.69
12c	8.55	9.11	9.66	10.22	10.77	11.33	11.88	12.43	12.99	13.54	14.10	14.65
14c	9.52	10.07	10.63	11.18	11.73	12.29	12.84	13.40	13.95	14.51	15.06	15.62
16c	10.48	11.04	11.59	12.14	12.70	13.25	13.81	14.36	14.92	15.47	16.02	16.58
18c	11.44	12.00	12.55	13.11	13.66	14.22	14.77	15.33	15.88	16.43	16.99	17.54
20c	12.41	12.96	13.52	14.07	14.63	15.18	15.73	16.29	16.84	17.40	17.95	18.51
22c	13.37	13.93	14.48	15.03	15.59	16.14	16.70	17.25	17.81	18.36	18.92	19.47
24c	14.34	14.89	15.44	16.00	16.55	17.11	17.66	18.22	18.77	19.32	19.88	20.43
26c	15.30	15.85	16.41	16.96	17.52	18.07	18.63	19.18	19.73	20.29	20.84	21.40
28c	16.26	16.82	17.37	17.93	18.48	19.03	19.59	20.14	20.70	21.25	21.81	22.36
30c	17.23	17.78	18.33	18.89	19.44	20.00	20.55	21.11	21.66	22.22	22.77	23.32
32c	18.19	18.74	19.30	19.85	20.41	20.96	21.52	22.07	22.62	23.18	23.73	24.29
34c	19.15	19.71	20.26	20.82	21.37	21.93	22.48	23.03	23.59	24.14	24.70	25.25
36c	20.12	20.67	21.23	21.78	22.33	22.89	23.44	24.00	24.55	25.11	25.66	26.22
38c	21.08	21.63	22.19	22.74	23.30	23.85	24.41	24.96	25.52	26.07	26.62	27.18
40c	22.04	22.60	23.15	23.71	24.26	24.82	25.37	25.92	26.48	27.03	27.59	28.14
42c	23.01	23.56	24.12	24.67	25.23	25.78	26.33	26.89	27.44	28.00	28.55	29.11
44c	23.97	24.53	25.08	25.63	26.19	26.74	27.30	27.85	28.41	28.96	29.52	30.07
46c	24.93	25.49	26.04	26.60	27.15	27.71	28.26	28.82	29.37	29.92	30.48	31.03
48c	25.90	26.45	27.01	27.56	28.12	28.67	29.22	29.78	30.33	30.89	31.44	32.00
50c	26.86	27.42	27.97	28.53	29.08	29.63	30.19	30.74	31.30	31.85	32.41	32.96
52c	27.83	28.38	28.93	29.49	30.04	30.60	31.15	31.71	32.26	32.82	33.37	33.92
54c	28.79	29.34	29.90	30.45	31.01	31.56	32.12	32.67	33.22	33.78	34.33	34.89
56c	29.75	30.31	30.86	31.42	31.97	32.52	33.08	33.63	34.19	34.74	35.30	35.85
58c	30.72	31.27	31.83	32.38	32.93	33.49	34.04	34.60	35.15	35.71	36.26	36.81
60c	31.68	32.23	32.79	33.34	33.90	34.45	35.01	35.56	36.12	36.67	37.22	37.78

Table IX will assist in calculating the number of bushels per acre of corn, at varying prices, which are necessary to pay the labor cost of production. The price per bushel is given at the top of the table, and the labor cost, as taken from Table VIII, is given at the left. The method of finding the number of bushels per acre is the same as was explained for finding the combined cost of man and horse labor. For example, if the total labor cost is $12.14, and the price per bushel is 40c, we find the $12.14 on the left and follow this across horizontally until we reach the column headed 40c where we find that the number of bushels per acre, at 40c per bushel, required to pay for that labor cost of production is 30.35 bu.

TABLE IX: Showing the number of bushels of corn per acre necessary to pay the labor cost of production at various costs and prices per bushel, no credit being allowed for value of stover.

Value of labor per acre	Price of corn per bushel										
	30c	35c	40c	45c	50c	55c	60c	65c	70c	75c	80c
$7.59	25.30	21.69	18.98	16.87	15.18	13.80	12,65	11.68	10.84	10.12	9.49
9.11	30.37	26.03	22.78	20.24	18.22	16.56	15.18	14.02	13.01	12.15	11.39
10.[illegible]	35.43	30.37	26.58	23.62	21.26	19.32	17.72	16.35	15.19	14.17	13.29
12.14	40.47	34.69	30.35	26.98	24.28	22.07	20.23	18.68	17.34	16.19	15.18
13.66	[illegible] 53	39.03	34.15	30.36	27.32	24.84	22.77	21.02	19.51	18.21	17.08
15.18	50.60	43.37	37.95	33.73	30.36	27.60	25.30	23.35	21.69	20.24	18.98
16.70	55.67	47.71	41.75	37.11	33.40	30.36	27.83	25.69	23.86	22.27	20.88
18.22	60.73	52.06	45.55	40.49	36.44	33.13	30.37	28.03	26.03	24.29	22.78
19.73	65.77	56.37	49.32	43.84	39.46	35.87	32.88	30.35	28.19	26.31	24.66
21.25	70.83	60.71	53.12	47.22	42.50	38.64	35.42	32.69	30.36	28.33	26.56
22.77	75.90	65.06	56.92	50.60	45.54	41.40	37.95	35.03	32.53	30.36	28.46
24.29	80.97	69.40	60.72	53.97	48.58	44.16	40.48	37.37	34.70	32.39	30.36

During the period 1905 to 1911, inclusive, the average annual area of corn in Ohio was 3,005,981 acres; the average annual total production was 112,773,950 bushels, or an average yield per acre of 37.52 bushels.* From the yearbooks of the United States Department of Agriculture for this same period the mean farm price of corn in Ohio on December first was found to be 51c. At this price per bushel for corn it would require 23.8 bushels to pay the labor cost of production previously mentioned—$12.14. This leaves a difference of 13.72 bushels, or, at 51c per bushel, $7.00, with which to pay for the fertilizer, seed, land rental, machinery cost, etc. When these expenses are paid there certainly cannot be much left as profits.

Referring to the contract labor table (Table VI) it will be noted that the hours of labor per acre actually reported are less than those shown in Table III, and that, at the assumed rates, the combined

*From the reports of the Ohio State Board of Agriculture.

labor cost exclusive of contract labor is but $11.47. From the same table it will be noted that on these fields there is an average of $1.27 per acre to be added for work done at a contract price, for which the hours of labor are not reported. This, added to the $11.47, brings the total labor cost for that class of fields up to $12.74 per acre.

TABLE X: Showing data in Table III grouped according to sections.

County	Number of fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre	
			Man	Horse	Man	Horse
Southeast section:						
Athens	1	2.83	213.75	160.00	75.53	56.54
Belmont	3	31.53	2,673.77	1,984.89	84.80	62.95
Coshocton	7	88.21	7,037.50	6,845.50	79.78	77.60
Harrison	2	13.61	971.00	759.50	71.34	55.80
Holmes	12	133.28	7,633.49	9,065.33	57.27	68.02
Meigs	6	8.85	863.75	710.75	97.60	80.31
Total	31	278.31	19,393.26	19,525.97	.....	....
Average	..	8.98	....	....	69.68	70.16
Northeast section:						
Ashtabula	1	4.21	273.44	267.22	64.95	63.47
Geauga	6	23.89	1,524.75	1,442.75	63.82	60.39
Lorain	2	7.37	632.50	646.50	85.82	87.72
Total	9	35.47	2,430.69	2,356.47	.. ..	.....
Average		3.94	....	....	68.53	66.44
Northwest section:						
Allen	10	112.97	6,493.25	6,910.50	57.48	61.17
Crawford	11	115.27	5,667.25	5,546.50	49.16	48.12
Hardin	7	76.37	3,103.32	4,151.24	40.64	54.36
Huron	8	96.10	4,755.19	5,966.65	49.48	62.09
Licking	3	29.56	1,437.25	1,616.00	48.62	54.67
Putnam	2	20.66	1,058.00	1,029.00	51.21	49.81
Seneca	1	12.01	660.75	514.25	55.02	42.82
Total	42	462.94	23,175.01	25,734.14	.....	.....
Average	..	11.02	....	....	50.06	55.59
Southwest section:						
Greene	2	7.47	307.50	304.75	41.16	40.80
Madison	4	122.81	4,686.50	5,261.25	38.16	42.84
Pickaway	6	202.34	8,380.81	8,923.76	41.42	44.10
Preble	11	252.53	7,406.50	13,989.00	29.33	55.40
Warren	3	39.33	1,723.75	1,584.50	43.83	40.29
Total	26	624.48	22,505.06	30,063.26	.....	.....
Average	..	24.02	....	....	36.04	48.14

REGIONAL DISTRIBUTION

For reasons shown later these records group themselves into four sections with reference to their distribution over the State, which sections may be called the Southeast, Northeast, Northwest and Southwest. In these records the Southeast section includes the counties of Adams, Athens, Belmont, Coshocton, Harrison, Holmes

and Meigs. The Northeast is represented by Ashtabula, Geauga and Lorain. The Northwest section includes Allen, Crawford, Hardin, Huron, Licking, Putnam and Seneca, while the Southwest includes Clinton, Green, Madison, Pickaway, Preble and Warren counties. Table X groups the data of Table III according to sections as defined.

When the average hours per acre shown by Table X are reduced to dollars and cents (at 16c per hour for man and 8c per hour for horse labor) it is found that in the Southwest section the labor of producing the corn crop amounts to $9.62 per acre, or $2.52 per acre less than the state average of $12.14. On the other hand, in the Northeast section the labor amounts to $16.28 per acre, and in the Southeast section it is $16.76 per acre, considerably above the average of the state, whereas the labor in the Northwest section is costing an average of $12.46 per acre, or only 32 cents per acre more than the average of the state.

Figures 4 and 5 show graphically the percentage comparison of the four groups outlined in Table X, with the state average of the 108 fields so grouped. Table XI gives in tabular form the same data as are shown in Figures 4 and 5.

TABLE XI. Showing relative amount of labor expended per acre in growing corn in the various sections of Ohio as compared with the State average, and the percentage variation from the State average in each section.

Partial items	Southeast section 31 fields, av. 8.98 A.		Northeast section 9 fields, av. 3.94 A.		Northwest section 42 fields, av. 11.02 A.		Southwest section 26 fields, av. 24.02 A.		State average 108 fields, av. 12.97 acres
	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre
Man labor									
Preparation of seed bed	9.21	16	11.86	50	8.12	3	6.97	—12	7.92
Planting	2.92	64	2.17	22	1.85	4	1.21	—32	1.78
Cultivating	15.52	57	11.53	17	9.13	—8	7.00	—29	9.89
Harvesting	26.65	27	33.37	59	22.95	9	16.29	—22	20.98
Total*	69.68	45	68.53	42	50.06	4	36.04	—25	48.18
Horse labor									
Preparation of seed bed	25.25	23	27.03	31	19.44	—6	18.88	—8	20.58
Planting	2.28	13	2.35	16	2.12	5	1.80	—11	2.02
Cultivating	12.28	—7	11.64	—12	13.00	—1	13.75	4	13.16
Harvesting	14.28	15	14.72	19	13.52	9	10.61	—14	12.40
Total*	70.16	27	66.44	20	55.59	3	48.14	—13	55.44

*As explained on page 90 several of the miscellaneous partial items have not been shown. The totals, however, include all partial items.

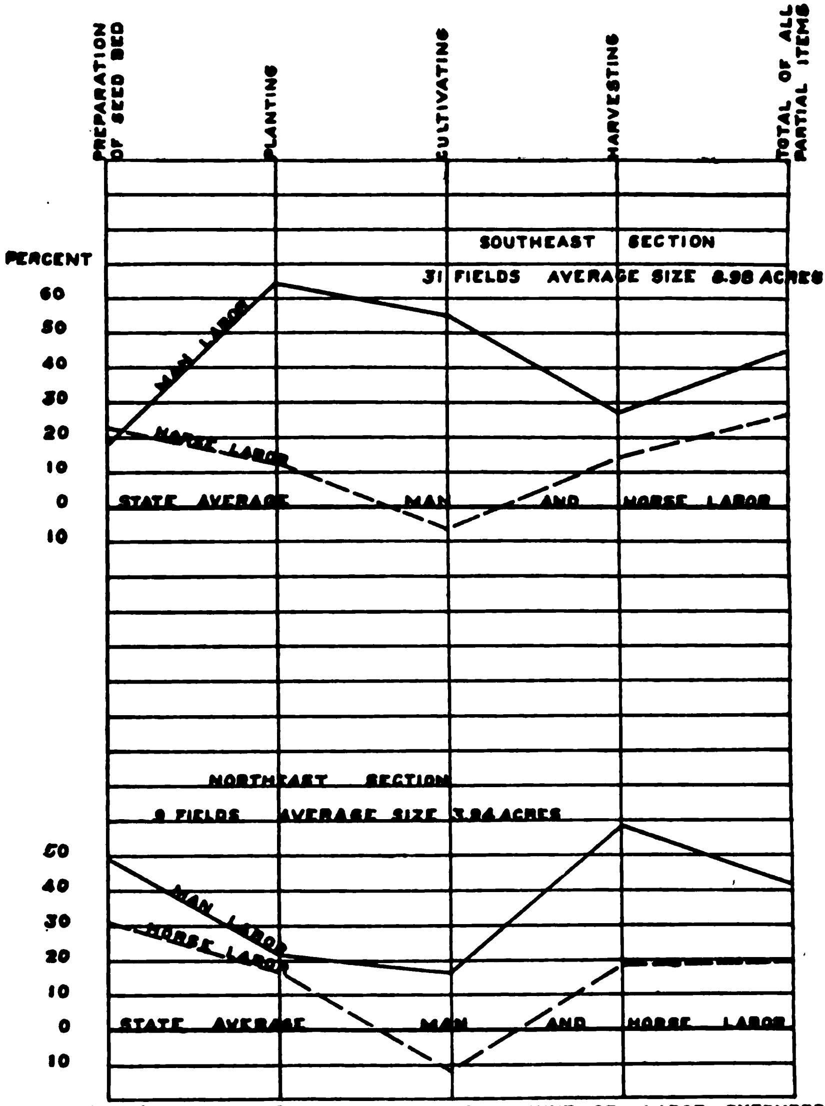

FIG. 4 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN THE SOUTHEAST AND NORTHEAST SECTIONS OF OHIO AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS

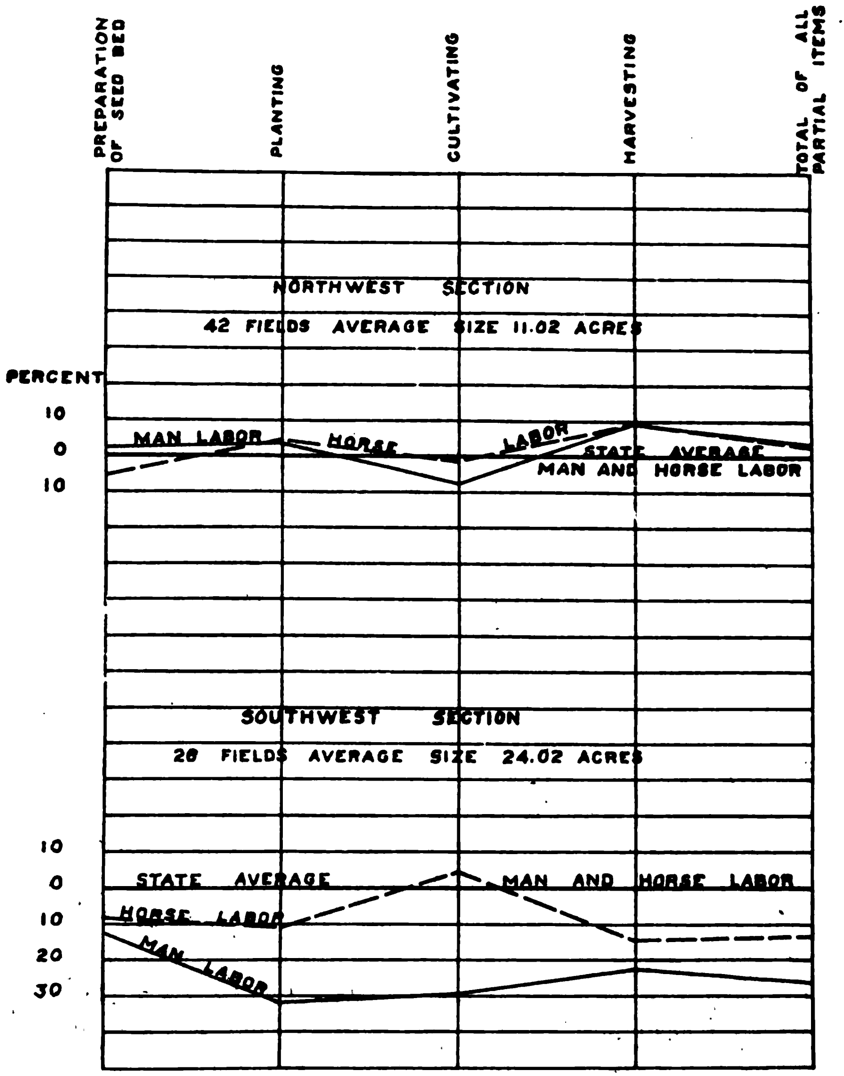

FIG. 5 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN THE NORTHWEST AND SOUTHWEST SECTIONS OF OHIO AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS

In these and succeeding charts of a similar nature the straight horizontal line is considered as the state average for both man and horse hours. Each partial item is then plotted as so many percent above or below the state average. For example, in Figure 4 the state average man hours for preparation of the seed bed is 7.92 hours. The average for the fields in the Southeast section is 9.21 hours, which is 16.3 percent more than the state average. Therefore, in Figure 4 the man hours for preparation of seed bed are plotted at 16 percent above the straight line which, as stated, represents the state average. Likewise the state average horse hours for the preparation of the seed bed is 20.58 hours. In the Southeast section 25.25 horse hours are required for this item, which is 22.69 percent more than the state average. Accordingly, in Figure 4 the horse hours for preparation of seed bed are plotted as 23 percent above the same straight line, since it represents the state average of horse hours as well as of man hours.

Tables X and XI or Figures 4 and 5 show that there is a gradual decrease in both man and horse hours per acre, as well as in the total labor cost per acre, in passing from the Southeast through the Northeast and Northwest to the Southwest section. There are a number of factors by which this decrease can be explained. In the Southeast section the topography is perhaps the greatest limiting factor. In this section the country is rough and broken, and while the average size of the farms is above the average of the State, yet the topography necessitates very irregular and not infrequently very small cultivated fields.

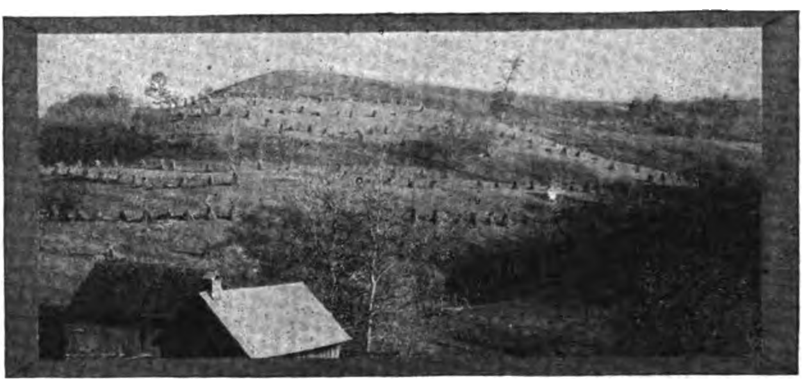

Fig. 6. Growing corn on the hillsides of Southeastern Ohio.

In the Northeast section the origin of the early settlers is probably an important factor, influencing as it does the type of farming, the size of farms and size of tools used. From a

topographic standpoint there is scarcely any reason why the farmers in this section should not use larger tools, utilizing more horses per man, and thus, in a measure, reducing the labor cost of production. However, the early settlers of this region came from New England, a rugged and broken country, where 70 to 80 acres were considered to be a large farm. They were thus familiar with the use of smaller tools and consequently adopted them in their work in Ohio. In this section also there is comparatively little tile drainage, the lack of which doubtless makes the soils heavier and harder to work, so that the farmers cannot use their labor so effectively. In the Northwest and especially the Southwest sections the influence of the more level country, better drainage, the use of larger tools and of more horses per workman is apparent.

SIZE OF FIELD

However, the difference in labor cost cannot all be explained on the basis of regional distribution. The size of fields must also be taken into consideration. A great deal has been said and written regarding the size of farms. Many who are not engaged in farming, and even some farmers, believe that smaller farms better tilled would bring greater profits than the larger farms. There may be room for improvement in the cultural methods on the larger farms, but as Warren has shown in Bulletin 295, of the Cornell University Experiment Station, the small farms have many disadvantages. He shows that while the receipts per acre on small farms are more than on the larger ones, the single item of labor on the small farm is so great that it more than offsets the difference in receipts. This is true not only for man labor, but also for horse labor. While only a limited amount of farm management survey work has been done in this state, so far as we have gone the same conditions are found in the areas that have been surveyed. As a general rule small farms must mean smaller fields, and accordingly we would expect the labor cost to increase as the size of the field decreases. This we do find, as is shown by Table XII and Figures 7, 8 and 9, the data for which were secured by regrouping Table III. These tables show the average percentage variation due to size of fields as compared with the average of all the 108 fields. While the man and horse labor may not both decrease as the size of the field increases, yet the combined cost, expressed in dollars and cents, does constantly decrease as the size of the field increases. In Table XIII will be found a probable explanation as to why the man or horse hours do not decrease uniformly as the size of fields increase.

TABLE XII. Showing relative amount of labor expended per acre in growing corn on various sized fields, and the percentage variation from the State average for each group of fields.

Partial items	Group .01—2.49 A. 15 fields, av. 1.65 A.		Group 2.5—4.99 A. 12 fields, av. 3.73 A.		Group 5—9.99 A. 19 fields, av. 7.50 A.		Group 10—14.99 A. 33 fields, av. 12.22 A.		Group 15—19.99 A. 8 fields, av. 17.72 acres		Group 20—24.99 A. 10 fields, av. 21.52 acres		Group 25 A. and over, 11 fields, av. 39 acres		State average 108 fields, av. 12.97 A.
	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre
Man labor															
Preparation of seed bed	12.89	63	9.26	17	10.06	27	8.40	6	7.37	—7	6.23	—21	7.38	—7	7.92
Planting	3.94	121	1 49	—16	2 29	29	2.33	31	1.86	4	1.13	—36	1.32	—26	1.78
Cultivating	22.43	127	11.52	16	15.57	57	10.69	8	9.20	—7	8.31	—16	7.40	—25	9.89
Harvesting	31.69	51	28.22	34	26.19	25	24.64	17	22.89	9	15.14	—28	16.81	—20	20.98
Total*	84.79	76	59.53	24	62.03	29	56.63	18	50.76	5	36.20	—25	37.14	—23	48.18
Horse labor															
Preparation of seed bed	26 69	30	23.55	14	22.58	10	21.66	5	21.00	2	18.28	—11	19.30	—6	20.58
Planting	3 28	62	2.40	19	2 47	22	2.05	2	2.14	6	1 63	—19	1.88	—7	2.02
Cultivating	12.92	—2	12.36	—6	13.03	—1	12.49	—5	11.77	—11	14.91	13	13.54	3	13.16
Harvesting	12.91	4	14.82	20	12.19	—2	13.43	8	16.04	29	10.46	—16	11.04	—11	12.40
Total*	69.21	25	63.31	14	57.72	4	60.53	9	59.84	8	50.07	—10	49.81	—10	55.44

*See foot note to Table XI.

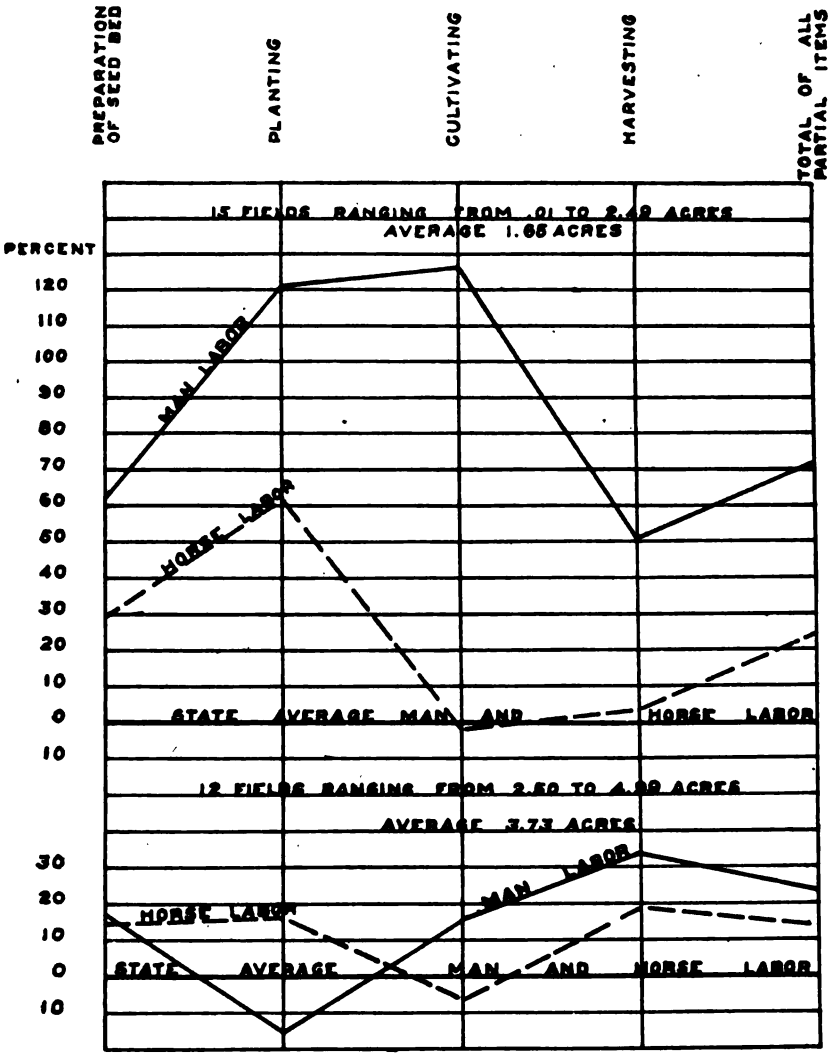

FIG. 7 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN VARIOUS SIZED FIELDS AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS AVERAGING 12.97 ACRES

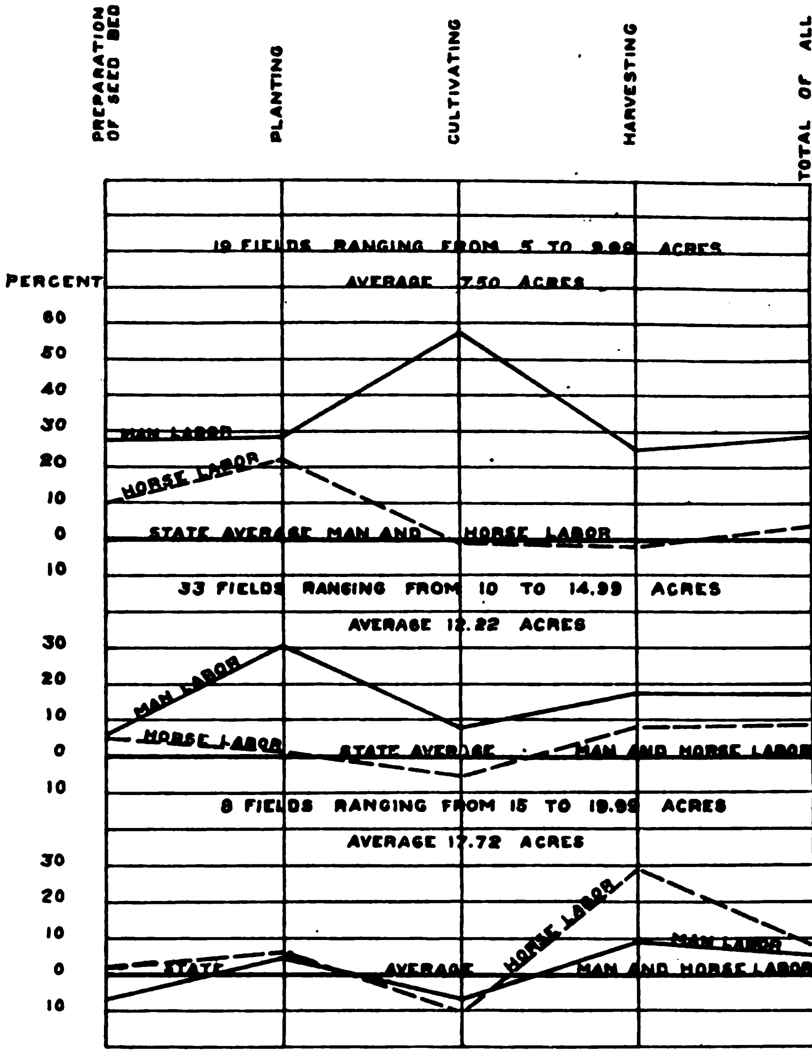

FIG. 8 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN VARIOUS SIZED FIELDS AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS AVERAGING 12.97 ACRES

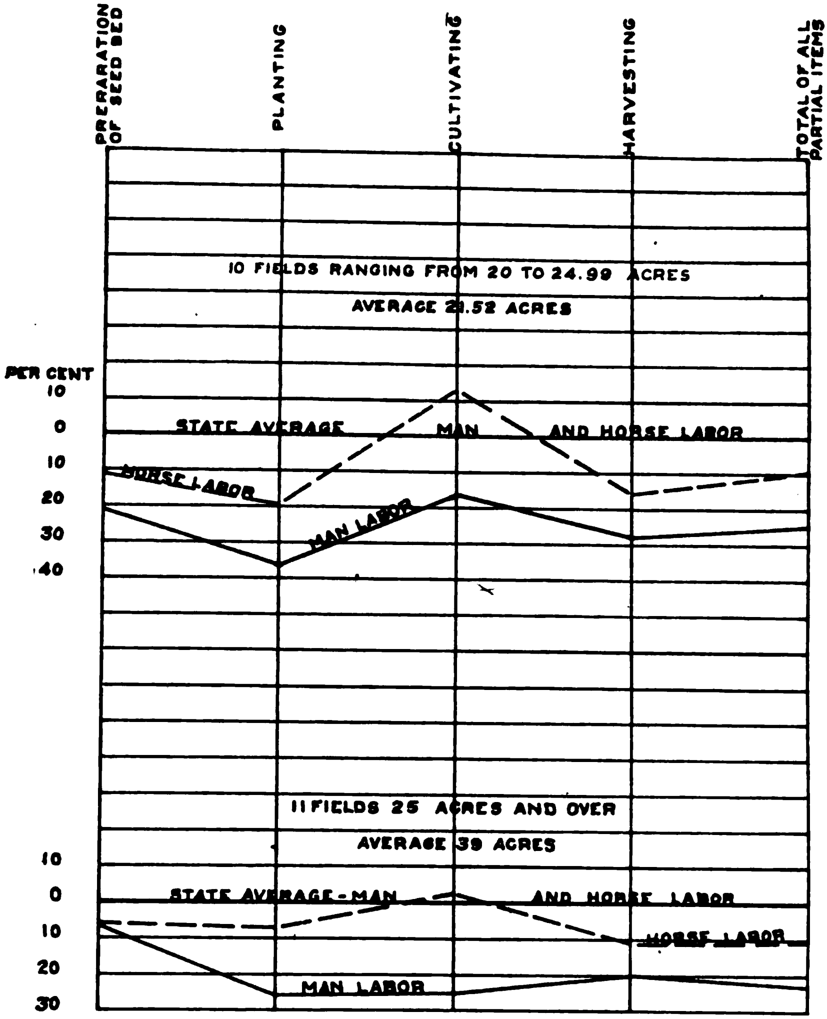

FIG. 9 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN VARIOUS SIZED FIELDS AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS AVERAGING 12.97 ACRES

TABLE XIII: Showing fields classified by size and location in the state.

Group division. acres	Total number of fields in group	Total area of all fields in group	Southeast		Northeast		Northwest		Southwest	
			Fields percent	Acres percent	Fields percent	Acres percent	Fields percent	Acres percent	Fields percent	Acres percent
.01-2.49	15	24.74	46.67	43.61	26.66	24.09	26.67	32 30	.....	.....
2.50-4.99	12	44.75	16.67	15.93	33.33	33.68	25 00	26.57	25.00	23 82
5.00-9.99	19	143.58	36 84	35.87	.....	.....	52.63	55 38	10 53	8.75
10.00-14.99	33	403.22	36.36	36 02	3.03	3.58	51.52	51.07	9 09	9.33
15.00-19.99	8	141.77	25.00	22.61	.....	.....	50.00	50.52	25 00	26.87
20.00-24 99	10	215.17	.....	.....	.....	.....	40.00	40.21	60.00	59.79

This table shows that, in any grouping of fields according to size, one region may predominate and hence the custom prevailing in the predominating region will greatly influence the total cost in that group. This is shown to a marked degree in the group .01 to 2.49 acres. In this group practically 47 percent of all the fields are in the Southeast section, and as shown in Table X, this section has the highest labor cost regardless of the size of the fields.

Further study of Figures 7, 8 and 9 or of Table XII reveals two pronounced cases in which the amount of man labor does not vary in accordance with the size of the fields. One is the time required for planting the fields averaging 3.73 acres, and the other is that required for cultivating the fields averaging 7.50 acres. Thesel exceptions are due, in a large measure at least, to the cultura methods. It so happens that in the first case all of the fields included were either drilled or planted with a check row planter. No time was spent in "marking out", and only one field had any replanting and that amounted to only one-half hour. In the second case, Table XIII shows that 37 percent of the fields are in the Southeast section, and 53 percent in the Northwest section. In both of these sections considerable hand labor (hoeing) was done. In fact, in all but 5 of the 19 fields included in the group averaging 7.50 acres, the hoe was used extensively as an implement of tillage; the average time of hoeing for all of the fields when used as explained in the footnote to Table XVIII on page 120 was 7.44 hours per acre, or 9.86 hours per acre for the fields in which hoeing was actually done. As these records cover a series of years and the fields are in various sections of the State, it is hardly probable that the climatic conditions were such as to require this amount of hoeing, or even a very large portion of it, in addition to the usual cultivation.

In Figure 7 the curve for the fields averaging 1.65 acres, shows that the man labor exceeds the horse labor in every partial item, varying from 50 to 126 percent. This of course indicates that a large amount of hand labor was done on these fields. However, where only a small acreage is grown annually the cost of hand labor may

be less than the interest on investment, taxes, insurance, depreciation and repairs on improved machinery, together with the cost of the horse labor necessary to operate the machinery.

The data at hand are not sufficient to justify the drawing of any conclusions when the fields are classified according to size in a given section, and compared with the average of all the fields in that section. However, charts (not shown here) which have been prepared from such data, seem to indicate that the size of fields in any section bears approximately the same relation to the average of that section as the average of any size in the State bears to the average of all the fields in the State. (See Figures 7, 8 and 9.)

SHAPE OF FIELDS

Another factor, which is more or less important in the labor cost of producing corn, is the shape of the field. Obviously, the shape of the farm has much to do with the shape and arrangement of the fields. Here again topography must be considered, since the fences frequently follow the contours of the surface. Fields having four sides, no two of which are parallel, or many sided and irregular shaped fields, naturally have a great many "point rows." With heavy horses and implements or with three, four or five horse teams, considerable time is lost in making the extra turnings due to these point rows.

Of the 108 fields under consideration, we have been able to classify 53 percent as rectangular. Comparing the average of all the rectangular fields with the average of all the other fields, we find but little difference in the labor required. But, by reclassifying these according to area, it is found that, generally speaking, there is a difference in the amount of labor required in favor of the rectangular fields. In Figure 10 it is shown that in the group of 15 fields averaging 1.65 acres the total labor cost of the rectangular fields is less than of the misshapen ones, but this is not uniformly true of the various partial items in this group. This may be due to the fact that the work is largely hand labor, which should not vary a great deal with the shape of the field. The 12 fields averaging 3.73 acres (shown in Figure 7 but not shown in Figure 10) have only a few fields which are not rectangular, so no comparison can be made. Likewise, no comparison can be made in the group averaging 17.72 acres (shown in Figure 8 but not shown in Figure 11) because there is only one rectangular field in this group. In the groups averaging 7.50 acres (Figure 10), 12.22 acres and 21.52 acres (Figure 11) it will be observed that in every case the labor cost of the rectangular fields is considerably lower than that of the misshapen ones. Table XIV gives in tabular form the same data as are shown by Figures 10 and 11.

TABLE XIV. Showing relative amount of labor expended per acre in growing corn on rectangular and misshapen fields of various sizes, and the percentage variation from the State average for groups of the same size.

Field groupings and partial items	Man hours					Horse hours				
	Rectangular fields		Misshapen fields		State average	Rectangular fields		Misshapen fields		State average
	Hours per acre	Variation percent	Hours per acre	Variation percent		Hours per acre	Variation percent	Hours per acre	Variation percent	
Fields ranging from .01-2.49 A.	10 fields, av. 1.70 A.		5 fields, av. 1.54 A.		15 fields, av. 1.65 A.	10 fields, av. 1.70 A.		5 fields, 1.54 A.		15 fields, av. 1.65 A.
Preparation of seed bed	11 26	−13	16.48	28	12.89	23.52	−12	33.71	26	26.69
Planting	4.38	11	2.96	−25	3.94	3 39	3	3 05	−7	3.28
Cultivating	21.80	−3	23.82	6	22.43	12 60	−2	13 62	5	12.92
Harvesting	33.31	5	28.09	−11	31.69	12.84	−1	13.07	..	12.91
Total*	83.58	−1	87.47	3	84.79	66.22	−4	75.84	10	69.21
Fields ranging from 5.00-9.99 A.	10 fields, av. 7.36 A.		9 fields, av. 7.67 A.		19 fields, av. 7.50 A.	10 fields, av. 7.36 A.		9 fields, av. 7.67 A.		19 fields, av. 7.50 A.
Preparation of seed bed	8.86	−12	11.34	13	10.06	20.04	−11	25.28	12	22.58
Planting	1.96	−14	2.61	14	2.29	2.40	−3	2 55	3	2 47
Cultivating	13.16	−15	18.13	16	15.57	12.03	−8	13.99	7	13.03
Harvesting	27.22	4	25.09	−4	26.19	12.43	2	11.94	−2	12.19
Total*	57.45	−7	66.91	8	62.03	50.31	−13	65.08	13	57.72
Fields ranging from 10.00-14.99 A.	19 fields, av. 12.50 A.		14 fields, av. 11.33 A.		33 fields, av. 12.22 A.	19 fields, av. 12.50 A.		14 fields, av. 11.33 A.		33 fields, av. 12.22 A.
Preparation of seed bed	7.81	−1	9.24	1	8.40	19.81	−8	24 31	12	21.68
Planting	2.35	1	2.29	−2	2.33	1.98	−3	2.14	4	2.05
Cultivating	9.84	−8	11.91	11	10.69	12.21	−2	12.88	3	12 49
Harvesting	23.73	−4	25.94	5	24.64	13 59	1	13.18	2	13 43
Total*	53.55	−5	61.06	8	56.63	57.02	−6	65.57	8	60.53
Fields ranging from 20.00-24.99 A.	4 fields, av. 20.84 A.		6 fields, av. 21.96 A.		10 fields, av. 21.52 A.	4 fields, av. 20.84 A.		6 fields, av. 21.96 A.		10 fields, av. 21.52 A.
Preparation of seed bed	5.75	−8	6.54	5	6.23	18.64	2	18.06	−1	18.28
Planting	.97	−14	1.23	9	1.13	1.46	−10	1.73	6	1.63
Cultivating	7.17	−14	9 02	9	8.31	14.90	..	14.92	..	14.91
Harvesting	9.02	−40	19.00	25	15.14	6.06	−42	13.25	27	10.46
Total*	22.91	−37	42 48	17	36.20	41.04	−18	53.78	7	50.07

*See foot note to Table XI.

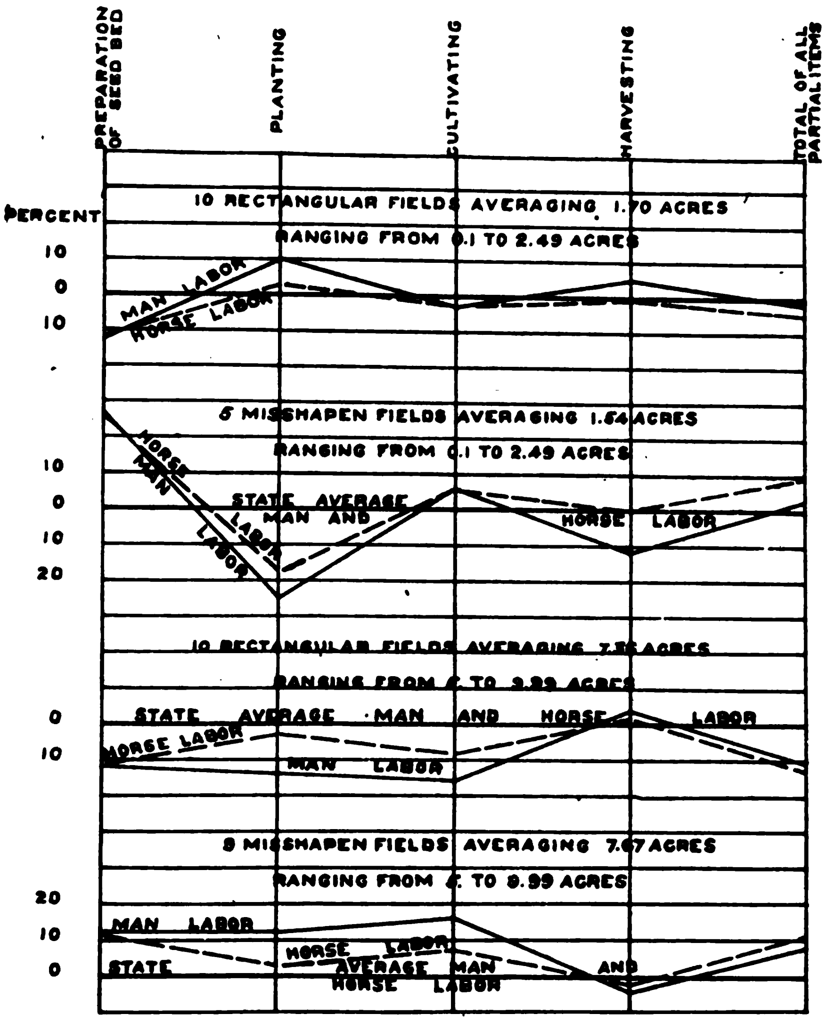

FIG. 10 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN ON RECTANGULAR AND MISSHAPEN FIELDS AS COMPARED WITH THE STATE AVERAGE OF FIELDS OF SIMILAR SIZE

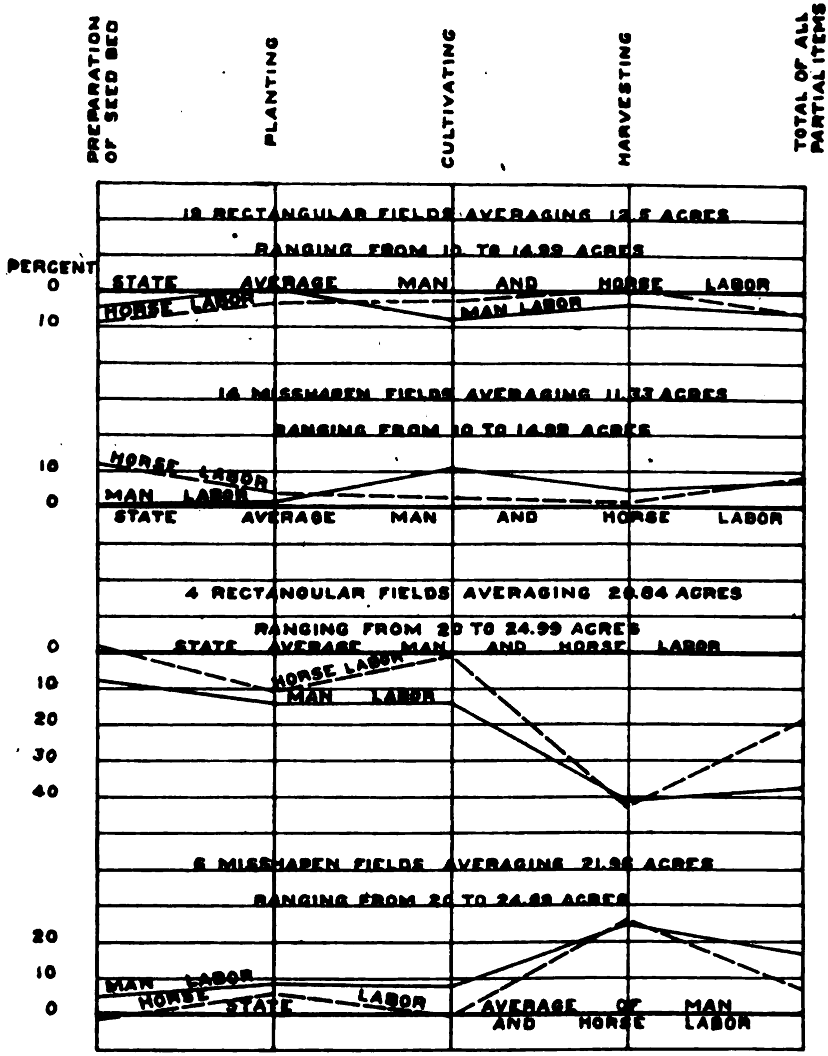

FIG. 11 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN ON RECTANGULAR AND MISSHAPEN FIELDS AS COMPARED WITH THE STATE AVERAGE OF FIELDS OF SIMILAR SIZE

In comparing the ratio of the width to the length of rectangular fields it is found that where the length is three times the width the total labor cost is less than where it is twice the width; where the length is twice the width the labor cost is less than where the sides are more nearly of equal length. This, however, is not uniformly true for each partial item.

TABLE XV: Showing that the method by which the crop is harvested has no appreciable effect on the labor cost of the partial items.

		Average of all fields shown in Table III	Average of all fields harvested by same general method as those of Table III	Average of all fields harvested in any manner whatsoever
Applying fertilizer:	Number of fields	82	97	153
	Average size of field: acres	12.79	12.40	12.50
	Hours per acre—man	3.48	5.27	4.83
	Hours per acre—horse	8.43	8.29	7.52
Care of seed:	Number of fields	82	89	144
	Average size of field: acres	14.29	13.84	13.50
	Hours per acre—man	.82	.79	.81
	Hours per acre—horse	.08	.08	.08
Preparation of seed bed:	Number of fields	108	122	202
	Average size of field: acres	12.97	12.53	12.65
	Hours per acre—man	7.92	8.07	8.58
	Hours per acre—horse	20.58	20.62	21.69
Planting:	Number of fields	108	125	204
	Average size of field: acres	12.97	12.68	12.77
	Hours per acre—man	1.78	1.79	1.83
	Hours per acre—horse	2.02	2.07	2.12
Cultivating:	Number of fields	108	125	204
	Average size of field: acres	12.97	12.68	12.75
	Hours per acre—man	9.89	9.95	9.81
	Hours per acre—horse	13.16	12.87	12.86
Harvesting:	Number of fields	108	121	180
	Average size of field: acres	12.97	12.84	13.30
	Hours per acre—man	20.98	20.89	20.69
	Hours per acre—horse	12.40	12.39	13.10
Miscellaneous labor:	Number of fields	27	38	68
	Average size of field: acres	10.53	10.30	10.89
	Hours per acre—man	.34	.53	.58
	Hours per acre—horse	.12	.24	.26
General farm labor:	Number of fields	108	125	206
	Average size of field: acres	12.97	12.68	12.74
	Hours per acre—man	2.82	2.88	2.68
	Hours per acre—horse	.90	.88	.86

In making a study of partial items the question also arises whether or not the manner in which the crop is to be harvested has any effect upon the time required to prepare the seed bed, plant or cultivate the crop. For example, if a field is to be hogged off will the farmer spend less time in cultivating that field than he would a field which he is expecting to put in the silo or cut and husk in some manner? Table XV, showing the actual average time per acre, compares item by item the average of the fields shown in Table III (1) with all fields harvested in the same general method, regardless of any variation in the number of fields

in each partial item, and (2) with all fields, regardless of the method in which they were handled or harvested. This table shows that the method of harvesting has no appreciable effect on the other partial items, such as preparing the seed bed, planting, cultivating, etc. This being the case, the larger number of fields will be used in discussing both the partial item labor costs and also the cost per acre, once over, of the various operations. The variation in the number of fields and in the average size of fields is due to the fact that in any particular partial item, only those fields actually operated upon are considered. The acreage is not the same in all the partial items for various reasons. Climatic conditions during the summer and fall may, for example, decrease the harvested area as compared with that which was prepared or planted. Or again, not all farmers manure or fertilize their corn ground; nor do all test or grade their seed corn. These and similar reasons account for the variations just mentioned.

Fig. 12. Efficient use of labor.

In studying these various partial items, a number of interesting features and comparisons are found. Harvesting is the largest single item. The man labor in harvesting amounts to more than 40 percent of the total man labor required to produce the crop, while the combined man and horse labor cost in this item is approximately 34 percent of the total labor cost. If the average hours of labor shown in Table IV (23.38 man and 41.21 horse) be subtracted from the average of Table III (48.18 man and 55.44 horse), the difference, 24.80 man hours and 14.23 horse hours, represents the time

required for harvesting, a large part of which is saved when the corn is hogged off. These figures for harvesting are much the same as given in Table XV. If both are reduced to a money basis, it is found that the cost of harvesting, as determined by subtraction, exceeds that as shown in Table XV by only 75 cents per acre. (If the hours shown in Table IV be subtracted from the averages mentioned on page 97 (46.12 man and 55.37 horse) the time remaining for harvesting is 22.74 man hours and 14.16 horse hours or 41 cents per acre, more than the average shown in Table XV.)

Fig. 13. A method of harrowing for corn still practiced in some sections of Ohio.

The average yield of 87 of the 108 fields under consideration was 48.13 bushels per acre. Forty-four of these fields produced less than this, or an average of 36.57 bushels per acre, while 43 fields produced an average of 59.38 bushels per acre. Table XVI shows the labor cost of harvesting, as well as the total labor cost of these fields when classified according to yields per acre. From this table it will be seen that the total labor cost of the 43 fields having the average yield of 59.38 bushels per acre is but 50 cents per acre more than that of the 44 fields averaging only 36.57 bushels per acre, thus making the labor cost per bushel very much lower for the 43 fields having the higher yield. Likewise, it will be seen that the labor cost does not increase correspondingly as the yield per acre increases, and the labor cost per bushel of course constantly decreases, until the yield of 74.85 bushels per acre is reached. It is probable that the high labor cost per bushel in the last class is not typical because of the smaller number of fields in the class and is caused largely by the smaller acreage of the fields and the much greater amount of hand labor on some of them.

TABLE XVI: Showing labor required for harvesting and total labor required for producing corn on fields classified according to yield.

Classification	Number of fields	Average size of fields	Labor cost per acre of harvesting			Total labor cost per acre			Average yield per acre	Total labor cost per bu.
			Man hours	Horse-hours	Cost at 16c and 8c	Man hours	Horse hours	Cost at 16c and 8c		
Fields producing less than 48 bu. per acre.........	44	11 75	20.66	12.06	$4.27	49.42	55.14	$ 12.32	36 57	33 7c
Fields producing more than 48 bu. per acre.......	43	12 15	22.63	13.83	4.73	50.37	58.28	12.72	59.38	21.4c
Fields producing less than 30 bu. per acre........	8	8 89	26.10	15.00	5.38	52.81	56.02	12.93	21.08	61.3c
Fields producing 30 and less than 40 bu. per acre.	16	13 77	17.62	9.77	3.60	41 37	50.78	10.68	33.96	31 4c
Fields producing 40 and less than 50 bu. per acre..	24	11.44	21 38	13.43	4.50	53 81	57.90	13.24	45.29	29.2c
Fields producing 50 and less than 60 bu. per acre.	17	14 35	22.82	11 52	4.57	47.90	51.13	11.75	55.29	21.3c
Fields producing 60 and less than 70 bu. per acre.	17	11 89	20.77	16.33	4 63	49.48	64 91	13.11	64.70	20.3c
Fields producing 70 bushels and over	5	5.40	41.44	1.60	6.76	92.75	83.79	21.54	74.85	28.8c

After harvesting, cultivation is the next largest item in reference to man labor, but preparation of the seed bed exceeds it in both the hours of horse labor and the total labor cost. The following table shows the ranking of the various partial items in hours of labor and also the approximate percentage each is of the total labor cost.

TABLE XVII: Showing labor relation of different partial items to each other.

Partial item	Approximate percent of total labor cost	Relative rank of amount of labor used		Hours of horse labor used per hour of man labor
		Man	Horse	
Harvesting	34	1	2	.63
Preparing seed bed	24	3	1	2.53
Cultivating	21	2	3	1.31
Fertilizing	11	4	4	1.66
Overhead labor ("General Farm")	4	5	6	.32
Planting	4	6	5	1.16
Care of seed	1	7	8	.01
Miscellaneous labor	1	8	7	.45

The preceding table, together with Table XV, reveals the fact that the overhead labor charge, or general farm labor, is considerably more than is generally supposed. In fact, it is usually disregarded entirely by farmers, whereas these figures show the overhead man labor per acre to be about 46 percent more than that required for planting; approximately one-third the time required to prepare the seed bed, and more than one-third the time of cultivating, yet all of these are well known operations in the production of corn, the importance of the cost of which no one will dispute.

By referring to Tables III, IV, V and VI on pages 95 and 96, it will be seen that with the exception of "hogged off" corn—Table IV—the total man hours nearly equal the total horse hours, and even where the harvesting is omitted there are less than two horse hours used per hour of man labor. This indicates that a great deal of hand labor is being done and that in some operations at least the horse labor is not being used to the best advantage. Table XVII shows that only a few of the partial items have much more than one horse hour per hour of man labor.

In Table XV were shown the partial item costs for all fields on which any work in connection with any particular partial item was performed, regardless of the times over or the acres covered. Table XVIII shows the labor cost per acre once over, of the more important operations.

TABLE XVIII: Labor required per acre, once over.

Operation	Total acres	Total hours		Hours per acre	
		Man	Horse	Man	Horse
Manure	662.73	7,816.72	11,697.14	11.79	17.65
Manure[1]	1,956.32	11,574.97	17 869.89	5.92	9.13
Care of seed	1 943.62	1 578.00	161.07	.81	.08
Preparation of seed bed:					
Plowing	2,654.70	14,428.38	34,929.85	5.44	13.16
Harrowing (spike)	3,210.41	3,170.48	8,617.71	.99	2.68
Discing	1,908.55	1,946.10	5,648.30	1.02	2.96
Planking	1,071.38	1,000.75	2 691.50	.93	2.51
Rolling[2]	842.64	641.00	1 353.25	.76	1 61
Planting:					
Marking out—1 horse	74.76	117.75	117.75	1.58	1.58
" " 2 horses	164.05	124.75	249.50	.76	1.52
Planting by hand	43.06	102.50	......	2.38	....
Drilling	224.10	335.50	407.00	1.50	1.82
Planting (2 horses)	1,592.79	1,488.00	2,975.00	.93	1.86
Replanting	638.73	1,183.25	....	1.85	....
Replanting[1]	1 158.67	1 354.75	....	1.17	....
Cultivating:					
Harrowing after planting	493.40	348.00	808.00	.71	1.64
Rolling after planting	368.01	259.00	515.00	.70	1.40
Using weeder	292.00	214.73	214.73	.74	.74
Cultivating (2 horses)	2,788.19	4,675.00	9,350.00	1.68	3.36
Hoeing	459 16	5,615.75	....	12.23	....
Hoeing[1]	1 649.67	7 792.50	....	4.72	....
Harvesting:					
Cutting by hand	576.66	5,226.50	....	9.06	....
Cutting by machine	565.62	1,428.37	2 181.62	2.53	3.86
Cutting silage corn by machine	95.79	247.63	479.13	2.59	5.00
Shocking	414.52	1,463.00	......	3.53	....
Picking up ear corn after binder	267.44	429.50	596.00	1.61	2.23
Filling silo[3]	144.50	3,356.63	2,818.38	23.23	19.50
Husking by hand	555.49	8,004.50	......	14.41	....
Hauling corn[4]	715.51	2 788.00	4,618.25	3.90	6.45
Hauling fodder[4]	348.80	853.75	1,165.00	2.45	3.34
Snapping, jerking and husking from stalk	156.93	1,690.75	2,165 25	10.77	13.80
Husking and shredding	353.30	4 497.75	4 245.75	12.73	12.02
Shredding	121.41	600.50	525.50	4 95	4.33
Hauling shock corn	31.48	225.00	285.00	7.15	9.05
Hauling fodder for feed[5]	140.02	842.00	1 234.00	6.01	8.81

[1]This includes the fields in the preceding item and in addition those in which only a part of the area was covered. The total area of fields, even though partly untreated, has been used in the calculations in connection with this item.

[2]The man hours include some labor done by boys which has been reduced to the equivalent of man time.

[3]Includes the time for cutting the corn in the field.

[4]After corn has been husked from shock in field.

[5]Only one farm. The time shown doubtless includes time required to feed fodder to cattle.

In studying the preceding table in connection with Table XV, it is found that the man labor of plowing is 63 percent and the horse labor 61 percent, respectively, of the labor of preparing the seed bed. In planting it is seen that the man labor per acre of replanting is more than is required to make the first planting by machine. Replanting was done on 86 out of 168 fields, hence it is an item of considerable importance as judged by the farms under consideration. If this time of replanting had been spent in testing and repairing the planter, testing seed corn, etc., during the period when crop work was at a standstill, a great deal of valuable time could doubtless have been put on other crops during the growing season, to say nothing about the more uniform stand of corn.

A few points in connection with the cultivation of corn as pronounced by Table XVIII deserve special mention. Out of a total of 204 fields there were 133 fields, with a total of 1,649.67 acres, on which the hoeing amounted to 4.72 hours per acre for the entire area, as explained in the foot note. This includes a total of 384.25 man hours for uncovering, setting up and thinning. Of these 133 fields there were 55, with a total of 459.16 acres, on which the average time of hoeing the entire area was 12.23 man hours. On dividing the total time for hoeing (7,792.5 man hours) by the total acreage (2,600.98) of the 204 fields cultivated, it is found that the hoeing amounts to 3 man hours per acre, which is practically 31 percent of the total man labor (9.81 hours) or 18 percent of the total labor cost of cultivation. From these figures it is manifest that a vast amount of hand labor, especially in cultivating, is being done. The experience of some of those men who have cooperated in this work proves that if only a part of this time be spent in more thorough preparation of the seed bed and in the cultivation, other than hoeing, of the crop, the profits will be equally as great and the task not so disagreeable.

As previously stated, it is the purpose of this Bulletin to discuss some of the phases of the labor cost of producing corn. However, in order that an approximate total cost may be determined, the following table based upon our records is added.

TABLE XIX: Costs other than labor—per acre.

Item	Number of fields reported	Minimum	Maximum	Average of all
Value of fertilizer applied	73	$ .62	$ 4.01	$ 1.46
Value of seed used	173	.05	2.32	.28
Value of twine used	70	.08	.38	.18
Machinery cost	176	.30	4.12	1.34
Land rental	170	1.27	6.88	3.81
General farm cash expense	128	.03	1.99	.42
Husking and shredding charge	18	1.00	2 91	1.97
Shredding charge	13	.46	.86	.61
Filling silo	5	1.24	1.61	1.36
Fuel	36	.03	.57	.25

The foregoing are the figures as they have been worked out for the various farms, but since no definite study of them has been made, they are not presented with the idea that they are surely correct. They are given more as a basis on which to make estimates. However, upon comparison it is found that they are not materially different from the figures presented in Bulletin No. 73, of the Bureau of Statistics, U. S. Department of Agriculture.

In the preceding table the item of land rental is based on the inventoried value of the farms under consideration. The average figure is doubtless somewhat low, owing to the fact that a part of

the farms on which this work was done are in sections of the State where land in general is cheaper, and the inventories are of the entire farm rather than of the more valuable fields on which the corn was grown. In the typical corn belt region of Ohio, farms rent at from five to seven dollars per acre for the entire acreage.

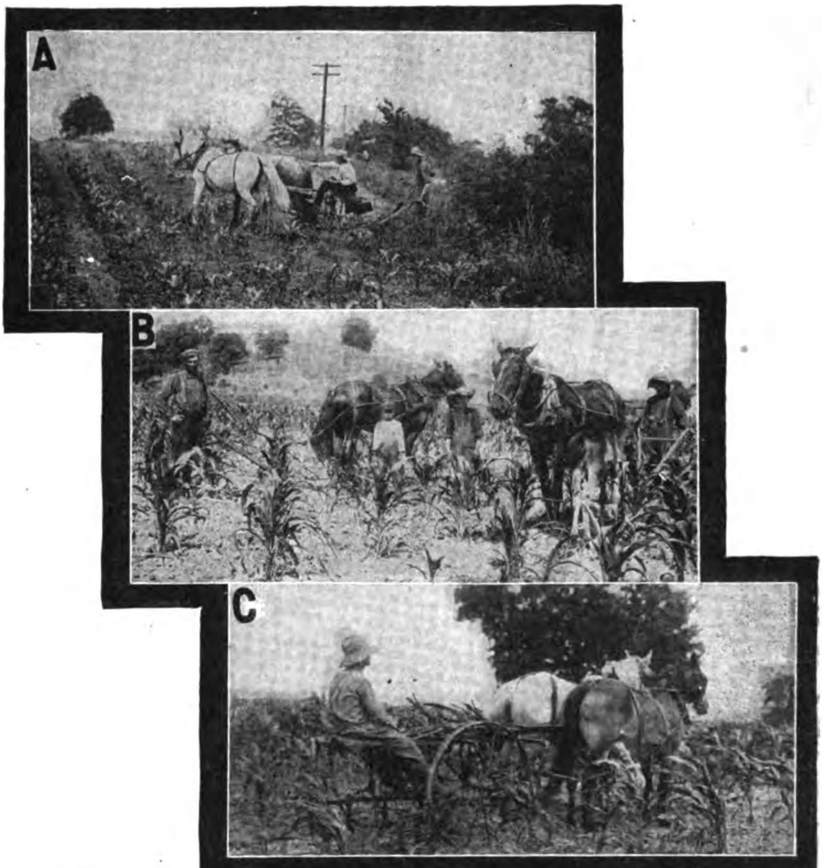

Fig. 14. Methods of cultivating corn as practised in Ohio. (A) Not common, but seen occasionally. (B) Inefficient use of man labor. (C) A quite common method, although the two-row worker is being rapidly introduced.

The preceding table has not taken into consideration the item of interest on the "cost until the crop yields a return," or the item of "insurance" against plant diseases, insects, floods, hailstorms and other weather conditions. This last item, like the first, is not actually paid for in cash, yet a certain percentage of the yield should be

deducted for insurance before figuring any profits. The value of the yield deducted should be allowed to accumulate as a fund to be drawn from when the crop fails or is damaged by some factor over which the producer has no control. The percentage of the yield to be deducted for insurance will depend upon the yield that is expected annually. The higher this gets above the average production of the State the greater should be the percentage set aside for insurance. The large yields per acre, which farmers have in mind when figuring costs, rarely ever materialize on the entire acreage planted. One hundred bushel yields by weight of merchantable corn are rare indeed; 75 bushel yields are not at all frequent.

While some of these items of cost seem of minor importance, yet all are items which must be considered before any profits can be figured. The failure to consider them misleads many people in figuring the cost of production upon their farms. The average field of corn in Ohio probably costs more than it is worth, unless the producer figures his labor at a very low rate.

SUMMARY

The labor cost is the largest single item in the total cost of producing corn.

From the fields under consideration it is found that the total labor required is 48.18 man hours and 55.44 horse hours; or. at 16 cents per hour for man and 8 cents per hour for horse labor, the cost is $12.14 per acre.

The cost in the different sections of the State, figured at 16c for man and 8c for horse labor is: For the Southwest section, $9.62; for the Northwest section, $12.46; for the Northeast section, $16.28; for the Southeast section, $16.76.

Replies from 34 Ohio municipalities having an average population of 5,831 show the average wage per hour for common laborers to be approximately 19c; for the common laborer with team, 44c. When figured at these rates the labor cost per acre of producing corn for the State is $16.08; for the Southwest section, $12.87; for the Northwest section, $16.46; for the Northeast section, $21.33, and for the Southeast section, $22.01.

In many cases the crop yield is not sufficient to pay for the single item of labor required to produce it unless the labor is figured at an extremely low rate.

Within certain limits, at least, the labor cost per acre is less on large fields than on small ones.

The man labor per acre of replanting, which is still a common custom, is more than is required to make the first planting by machine.

A large amount of hand labor, especially in cultivating, is done on the corn crop. It would seem that much of this could well be avoided.

The labor cost of harvesting is more than one-third the total labor cost. An appreciable amount of labor is therefore saved when the crop is harvested by livestock in the field.

THE VALUE OF SOYBEAN AND ALFALFA HAY IN MILK PRODUCTION

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., DECEMBER, 1913

BULLETIN 267

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OHIO AGRICULTURAL EXPERIMENT STATION

[1]With leave of absence. [2]In cooperation with Weather Service, U. S. Department of Agriculture.
[3]In cooperation with Bureau of Plant Industry, U. S. Department of Agriculture.
[4]In cooperation with Boys' Industrial School. [5]In cooperation with Ohio State Reformatory.

BULLETIN

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THE VALUE OF SOYBEAN AND ALFALFA HAY IN MILK PRODUCTION

BY R. E. CALDWELL*

INTRODUCTION

The purchase of nitrogenous feeds for dairy cows has in recent years assumed enormous proportions. As a general rule, these feeds are concentrates, such as the by-products: bran, middlings, linseed oil meal, cotton-seed oil meal, gluten feed and distillers' grains. Several of these with other feeds and filling materials have been mixed to form the so-called "ready to use" rations that are being rather widely distributed. The prevailing high prices of feeds in general and the great demand for feeds suitable for dairy cows have caused prices for these feeds to become very high; so high, in fact, that some dairymen have come to feel that they can scarcely afford to purchase them. The question naturally arises, "Must these feeds be used in order to produce dairy products at a profit, or may home-grown feeds be used in their places?" It is obvious that no answer can be given that will apply to all conditions. However, in order to secure data which may assist feeders to determine which course is best suited to the conditions with which they are dealing, two experiments have been conducted at this Station to compare such rations. The first will be discussed in Part I, and the second in Part II of this bulletin.

PLAN

The first experiment was planned to compare soybean hay with bran and cotton-seed meal as a source of protein. This experiment consisted of two tests; one conducted in 1908 and the other in 1909.

*Resigned October 5, 1911.

PART I

In selecting animals for this test, the following points were considered: producing capacity, breed, age, period of lactation and duration of pregnancy. Eleven cows were used in the 1908 test and nine in the 1909 test.

Tables I and II give the exact data regarding the points considered in the selection of the cows for these tests. These tables show that the two lots were quite similar, and the comparisons obtained are believed to be fair.

TABLE I. Cows used in the 1908 test.

Name of cow	Breed	Age yrs.-mos.	Date of calving	Date bred	Production of milk per day
Lot 1					Lbs.
Miami Pride	Guernsey	10-8	Nov. 21, 1907	Feb. 8, 1908	25.65
Topsy May	Jersey	6-0	Oct. 13, 1907	Feb. 27, 1908	19.35
Mantee Mahomet	Holstein	4-9	Oct. 7, 1907	Mar. 9, 1908	20.56
Teeny Gray 2nd	Jersey	2-9	Sept. 15, 1907	Jan. 11, 1908	14.67
Little May	Jersey	6-4	Aug. 29, 1907	Oct. 13, 1907	17.48
Average		5-8	....	....	19.54
Lot 2					
May's 2nd	Jersey	11-11	Nov. 9, 1907	....	21.25
Phillip's 4th	G. Guernsey	9-11	Nov. 10, 1907	Mar. 29, 1908	21.51
Grace Daw	Holstein	6-10	Sept. 23, 1907	Feb. 15, 1908	24.82
Fair Mahomet	Holstein	2-8	Sept. 12, 1907	Jan. 16, 1908	21.18
May 2nd Pedro	Jersey	4-0	Aug. 17, 1907	Mar. 9, 1908	12.45
Bessie Nervillette	Jersey	4-7	Dec. 4, 1907	Feb. 4, 1908	21.39
Average	....	8-8	....	....	20.43

TABLE II. Cows used in the 1909 test.

Name of cow	Breed	Age yrs.-mos.	Date of calving	Date bred	Production of milk per day
Lot 1					Lbs.
Grace Daw	Holstein	7-10	Nov. 16, 1908	Mar. 18, 1909	35.08
B. Nervilette	Jersey	5-7	Nov. 18, 1908	Feb. 17, 1909	21.68
May 2nd Pedro	Jersey	5-5	Dec. 10, 1908	Mar. 26, 1909	24.85
Teeny Gray 2nd	Jersey	3-9	Oct. 18, 1908	Jan. 23, 1909	16.46
Average	....	5-8	....	....	24.52
Lot 2					
Lady Thorne's 4th	Holstein	3-9	July 30, 1908	Nov. 8, 1908	26.91
Fair Mahomet	Holstein	3-8	Oct. 16, 1908	Feb. 28, 1909	23.60
Miami Pride	Guernsey	11-8	Oct. 29, 1908	Mar. 26, 1909	29.14
Little May	Jersey	7-4	July 20, 1908	Dec. 8, 1908	16.16
Topsy May	Jersey	7-0	Dec. 8, 1908	....	26.58
Average	....	6-6	....	....	26.26

During the entire time that the cows were under observation the milk of each cow was weighed and sampled separately at each milking. A container was provided for the samples from the milk of each cow, and the composite samples thus obtained were tested weekly for butterfat. The feeds were analyzed under the direction of Mr. J. W. Ames, chief in Chemistry at the Station, with results as shown in the following tables:

TABLE III: Composition of feeds used in the 1908 test—Lbs. per 100.

Name of feed	Water	Ash	Protein	Fiber	Nitrogen-free extract	Ether extract
Silage	76.825	.958	1.891	5.467	13.505	1.360
Soybean hay	12.748	7.855	11.627	28 850	36.684	2.236
Corn stover	20.252	4.383	4.248	26.931	42.141	2.045
Soybean hay, refuse	14.324	5.135	6 942	40.413	32.006	1.189
Corn stover, refuse	26 592	3.642	2.760	31.562	33.816	1.628
Cotton-seed meal	10.196	7.195	40.260	8.000	25.083	9.256
Bran	12.920	5.692	15 320	8.747	53.996	3.325
Corn meal	16.120	1.402	9.390	2.077	67.074	3.947

TABLE IV. Composition of feeds used in the 1909 test.—Lbs. per 100.

Name of feed	Water	Ash	Protein	Fiber	Nitrogen-free extract	Ether extract
Silage	68.36	1.26	2 20	8.12	19.24	.82
Soybean hay	13.83	6.10	13.52	25.71	37.80	3.04
Corn stover	12.22	5.24	5.73	26.25	49 00	1.56
Soybean hay, refuse	16.76	4.69	10.51	32.25	33 56	2.23
Silage, refuse	66.08	1.50	2.06	11.04	18.74	.58
Corn Stover, refuse	24.16	3.73	3 74	27.24	39.89	1.24
Cotton-seed meal	3.30	6.73	40.47	6.97	31.80	10.73
Bran	13.35	4.99	13.88	7.06	56.98	3.74
Corn meal	17.93	1.25	7.51	1.87	68.15	3.29

There was a slight difference in the composition of the feeds used in the two experiments. The moisture in the silage used for the two tests varied somewhat over 8 percent; the cotton-seed meal was also found to contain much less moisture in the second test (1909) than in the first test (1908); otherwise, the composition of the various feeds for the two tests was quite similar.

In both tests the rations for the corresponding lots were the same, and were as follows: Lot 1 in both tests received corn silage, soybean hay, and a grain mixture made up of 6 parts, by weight, of corn meal and 1 part of cotton-seed meal. Lot 2 in both tests received corn silage, corn stover and a grain mixture made up of equal parts, by weight, of corn meal, wheat bran and cotton-seed meal.

It will be noticed that, in both cases, Lot 1 received a ration in which a very small amount of purchased feed was used; while a relatively large amount of both bran and cotton-seed meal were used in the ration supplied to Lot 2 in both tests. The plan of feeding

during the preliminary and subsequent periods was the same except in the period subsequent to the second test, in which case two cows of Lot 1 were continued on soybean hay and two cows of Lot 2 were continued on bran and cotton-seed meal; while the remainder of both lots received mixed hay and silage as a roughage and corn and cotton-seed meal as grain.

The following prices of feeds and product were used in all calculations:

Wheat bran	$24.00	per ton
Corn meal	20.00	" "
Cotton-seed meal	30.00	" "
Corn silage	3.00	" "
Corn stover	4.00	" "
Soybean hay	8.00	" "
Alfalfa hay	10.00	" "
Milk (whole)	1.00	per cwt.
Milk (skim)	.15	" "
Butterfat	.25	per lb.

RESULTS OF THE FIRST TEST

In order to obtain definite data as to the performance of the various individuals when fed similarly, all cows in this test were fed for the preliminary period of 31 days the same ration received by Lot 1 during the test. They were then divided into two lots as shown in Table I, and were fed the rations given above. The comparison proper continued for 60 days and subsequent records were kept for 30 days, making in all 121 days.

FEEDS CONSUMED

Table V shows the amount of feed consumed by each lot during the 60 days.

TABLE V. Feed consumed during 60 days test, 1908.

Lot 1. Ration during test: corn silage, soybean hay, corn and cotton-seed meal.

Name of cow	Total lbs. feed consumed				Average daily lbs. feed consumed			
	Corn meal	Cotton-seed meal	Silage	Soybean hay	Corn meal	Cotton-seed meal	Silage	Soybean hay
Miami Pride	364.8	60.8	2,098	515	6.08	1.01	34.96	8.58
Topsy May	308.4	51.4	2,100	570	5.14	.86	35.00	9.51
Mantee Mahomet	358.8	59.8	2,029	448	5.98	.99	33.82	7.47
Teeney Gray 2nd	308.4	51.4	1,924	504	5.14	.86	32.08	8.41
Little May	308.4	51.4	1,891	525	5.14	.86	31.53	8.76
Average	329.7	54.9	2,008	512	5.49	.91	33.47	8.54

TABLE V. Concluded. Feed consumed during 60 days test, 1908.

Lot 2. Ration during test: corn silage, corn stover, corn, bran and cotton-seed meal

Name of cow	Total lbs. feed consumed					Av. daily lbs. feed consumed				
	Bran	Corn meal	Cotton-seed meal	Silage	Corn stover	Bran	Corn meal	Cotton-seed meal	Silage	Corn stover
May's 2nd	172	172	172	2,098	464	2.86	2.86	2.86	34.96	7.74
Phillip's 4th	150	150	150	2,100	459	2.50	2.50	2.50	35.00	7.65
Grace Daw	172	172	172	2,100	508	2.86	2.86	2.86	35.00	8.46
Fair Mahomet	172	172	172	2,088	400	2.86	2.86	2.86	34.81	6.67
May 2nd Pedro	150	150	150	2,050	538	2.50	2.50	2.50	34.17	6.43
Bessie Nervilette	150	150	150	2,095	441	2.50	2.50	2.50	31.53	8.76
Average	161	161	161	2,088	468	2.68	2.68	2.68	34.24	7.61

This table shows that the silage consumed per day was slightly greater in Lot 2 though the difference amounted to little. Lot 1 consumed somewhat more of the soybean hay than did Lot 2 of the stover. Less of the soybean hay was refused than of the stover. Owing to the coarse nature of these feeds, a large percentage of each was refused. The total number of pounds of grain consumed daily was greater with Lot 2, and these grains were the most expensive. The total amount of nutrients consumed by the two lots was practically the same.

The average daily nutrients consumed is shown in Table VI; also the composition of an average daily ration. Lot 2 received slightly more protein and fat, yet it is interesting to note how closely the two rations agree in total composition.

TABLE VI: Average daily nutrients consumed, 1908.

Name of cow	Protein (lbs.)	Crude fiber (lbs.)	Nitrogen-free extract (lbs.)	Ether extract (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal, cotton-seed meal				
Miami Pride	2.884	3.988	12.448	1.057
Topsy May	2.798	4.332	12.082	1.017
Mantee Mahomet	2.749	3.523	11.848	1.018
Teeny Gray 2nd	2.667	3.729	11.336	.964
Little May	2.681	3.841	11.374	.961
Average	2.756	3.883	11.818	1.003
Lot 2. Ration during test: corn silage, corn stover, bran, corn, cotton-seed meal				
May's 2nd	2.943	4.255	12.683	1.133
Phillip's 4th	2.703	4.158	12.119	1.071
Grace Daw	2.964	4.485	12.931	1.145
Fair Mahomet	2.911	3.907	12.298	1.113
May 2nd Pedro	2.654	3.729	11.596	1.040
Bessie Nervilette	2.693	4.060	12.273	1.066
Average	2.811	4.099	12.272	1.095

While there was some difference in the average daily production, it continued through all three periods. This with the equal amount of nutrients consumed must not be taken as proof that the nutrients in a given amount of roughage are equal in food value to an equal amount in grain; for rations rather than feeds are dealt with in this instance, and different roughages were used in the two rations, a lower grade being used in the ration for Lot 2.

TABLE VII: Average daily production of each cow, 1908.

Name of cow	31 days before test		60 days of test		30 days after test	
	Milk (lbs.)	Fat (lbs)	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn, cotton-seed meal						
Miami Pride	25.65	1.062	23.66	1.064	22.93	1.072
Topsy May	19.35	1.130	17.55	1.062	17.10	1.043
Mantee Mahomet	20.56	.580	19.81	.580	19.60	.524
Teeny Gray 2nd	14.67	.889	14.31	.857	14.34	.853
Little May	17.48	.948	16.31	.992	15.71	.923
Average	19.54	.926	18.29	.897	17.93	.883
Lot 2. Ration during test: corn silage, corn stover, bran, corn, cotton-seed meal						
May's 2nd	21.25	1.158	18.80	1.067	18.00	1.013
Phillip's 4th	21.51	1.041	19.03	.935	17.25	.864
Grace Daw	24.82	.759	24.95	.783	26.68	.861
Fair Mahomet	21.18	.686	21.63	.712	22.61	.695
May 2nd Pedro	12.45	.776	13.91	.874	14.01	.865
Bessie Nerviiette	21.39	1.176	18.90	1.106	17.73	1.037
Average	20.43	.932	19.53	.913	19.38	.885
Difference	.89	.006	1.24	.016	1.35	.002

Table VII shows that Lot 2 gave slightly more milk and butterfat daily per cow than Lot 1, but this difference did not change with a change of ration. This shows that the two rations were practically equal in feeding value so far as milk and butterfat production is concerned. These results are shown more graphically in Figure 1. The scale to the left represents pounds of milk daily and that ot the right represents pounds of fat daily. The solid lines represent the production of Lot 1 and the broken lines that of Lot 2.

While the production of milk and fat is the important point to dairymen, the gain or loss in live weight should be taken into consideration. Table VIII shows that the gain in each lot was practically the same, being less than one-half pound per cow per day.

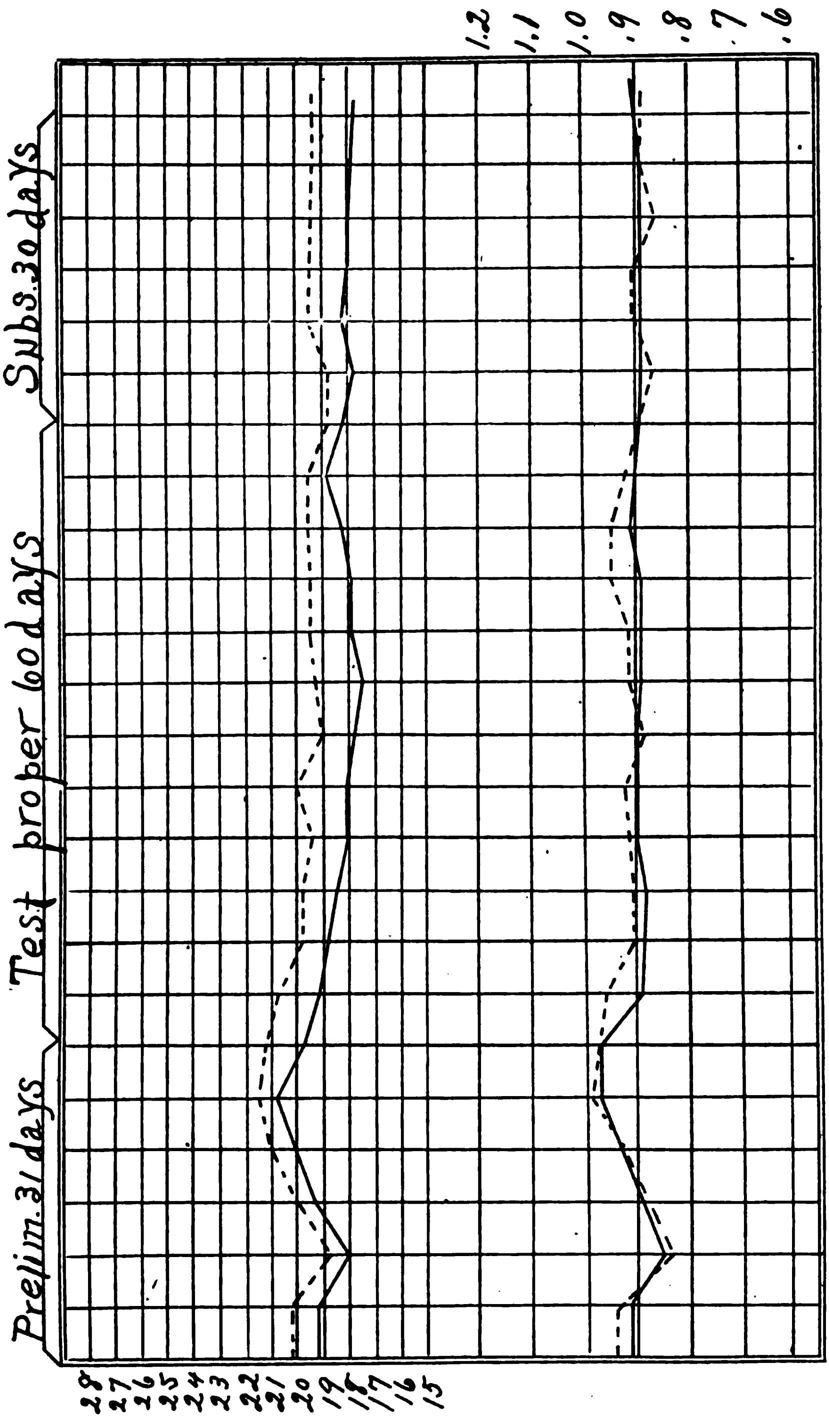
1.2 1.1 1.0 .9 .8 .7 .6
Prelim. 31 days
Test proper 60 days
Subs. 30 days
28 27 26 25 24 23 22 21 20 19 18 17 16 15

Figure 1.

TABLE VIII: Summary of weights, 1908.

Name of cow	Average weight at beginning of test (lbs.)	Average weight at end of test (lbs.)	Gain or loss (—) for 60 days (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn and cotton-seed meal			
Miami Pride	925	948	23
Topsy May	829	858	29
Mantee Mahomet	1,103	1 144	41
Teeny Gray 2nd	753	767	14
Little May	825	862	37
Average	867	915.8	28.8
Lot 2. Ration during test: corn silage, corn stover, bran, corn and cotton-seed meal			
May's 2nd	929	956	27
Phillip's 4th	968	998	30
Grace Daw	1,152	1,133	—19
Fair Mahomet	853	898	45
May 2nd Pedro	834	877	43
Bessie Nervilette	824	850	26
Average	926.6	952	25.3

Another method of measuring the relative efficiency of the two rations is to compare the amount of dry matter consumed per unit of product, milk or butterfat. This comparison is shown in Table IX, and indicates that the difference is very small.

TABLE IX: Amount of dry matter required to produce a unit of product, 1908.

Name of cow	Milk produced (lbs.)	Butterfat produced (lbs.)	Total dry matter consumed (lbs.)	Dry matter per 100 lbs. of milk (lbs.)	Dry matter per pound butterfat (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal					
Miami Pride	1,418.0	63.845	1,301.09	91.75	20.38
Topsy May	1,053.1	63.712	1,293.59	122 83	20.30
Mantee Mahomet	1,188.5	34.763	1,221.76	102.79	35.15
Teeny Gray 2nd	848.2	51.417	1,196.59	141.07	23.27
Little May	978.9	55.333	1,206.93	124.29	21.81
Average	1,097.3	53.814	1,243.99	113.36	23.23
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal					
May's 2nd	1,128.4	64.040	1,328.53	117.73	20.75
Phillip's 4th	1,141.8	56.096	1,267 40	111.00	22.59
Grace Daw	1,497.0	46.995	1,360.74	90.89	28.96
Fair Mahomet	1,297.9	42.654	1,278.98	98.54	29.99
May 2nd Pedro	834.5	52.816	1,202.28	144.07	22.76
Bessie Nervilette	1 134.0	66.335	1,264.75	111.47	19.07
Average	1 172.3	54.823	1 283.78	109.51	23.42

FINANCIAL STATEMENT

The average dairyman is interested in the relative efficiency of the two rations, because of the effect on the cost per unit of product. A financial statement is given in Table X; but it must be kept in mind that this statement is correct only when the prices given on page 128 are used. Any change in prices would affect the financial results.

TABLE X: Cost of feeds and value of product, 1908.

Name of cow	Cost of product				Value of product			
	Total cost of feed	Average daily cost of feed	Cost per 100 lbs. milk produced	Cost per pound butterfat produced	Butter-fat	Skim-milk	Total	Average daily value of product
Lot 1. Ration during test: corn silage, soybean hay, corn and cotton-seed meal								
Miami Pride......	$ 9.77	$ .163	$ .689	$ .153	$ 15 96	$2.03	$17.99	$ .300
Topsy May........	9 28	.155	.881	.146	15.93	1.48	17.41	.290
Mantee Mahomet..	9.32	.165	.784	.268	8.69	1.73	10.42	.174
Teeny Gray 2nd...	8.76	.146	1.033	.170	12.85	1.20	14.05	.234
Little May.........	8.79	.147	.898	.159	13.83	1.38	15.21	.254
Average.......	9.18	.155	.857	.179	13.45	1 56	15.01	.250
Lot 2. Ration during test: corn silage, corn stover, corn meal, bran and cotton-seed meal								
May's 2nd	$10.44	$ .174	$ .925	$ .163	$ 16.01	$1.60	$17.61	$ .294
Phillip's 4th.......	9.62	.160	.843	.172	14.02	1.63	15.65	.261
Grace Daw.........	10.53	.176	.703	.224	11.75	2.18	13 93	.232
Fair Mahomet....	10.29	.172	.793	.241	10.66	1.88	12 54	.209
May 2nd Pedro....	8.71	.145	1.044	.165	13.20	1.17	14.37	.240
Bessie Nervilette..	9.57	.160	.844	.144	16.58	1.60	18.18	.303
Average......	9.86	.164	.858	.185	13.70	1.68	15.38	.256

While profit is the practical test of the value of feeds, market conditions fluctuate to such an extent that no definite conclusions that will apply through a series of years can be drawn. This table shows that the cost of the product under the market prices which were applied was practically the same for both lots, although Lot 1 yielded the product at a slightly lower cost.

RESULTS OF THE SECOND TEST

Nine cows were used in this test, which was practically a repetition of the foregoing test. Lot 1 contained four cows, and Lot 2, five cows (See Table 2). The rations used were the same as those used in the previous test except that a change, as previously stated,

was made during the subsequent period, (See page 128). The test continued for 133 days—28 days preliminary, during which both lots were on the soybean ration, 77 days on the different rations, and 28 days subsequent to this period.

TABLE XI: Feed consumed during test, 1909.

Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal

Name of cow	Total pounds feed consumed				Average daily pounds feed consumed			
	Corn meal	Cotton-seed meal	Silage	Soybean hay	Corn meal	Cotton-seed meal	Silage	Soybean hay
Grace Daw	475.2	79.2	3,431	870	6.17	1.03	31.57	11.30
Bessie Nerviletta	475.2	79.2	2,596	594	6.17	1.03	33.72	7.71
May 2nd Pedro	475.2	79.2	1,980	628	6.17	1.03	25.71	8.16
Teeny Gray 2nd	422.4	70.4	2,311	634	5.49	.91	30.02	8.24
Average	462.0	77.0	2,329	681.7	6.00	1.00	30.25	8.85

Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal

Name of cow	Total pounds feed consumed					Average daily pounds feed consumed				
	Bran	Corn meal	Cotton-seed meal	Silage	Stover	Bran	Corn meal	Cotton-seed meal	Silage	Corn stover
Lady Thorne 4th	231.0	231.0	231.0	1,919	487.0	3.00	3.00	3.00	24.93	6.32
Fair Mahomet	231.0	231.0	231.0	2,399	440.0	3.00	3.00	3.00	31.15	5.72
Miami Pride	231.0	231.0	231.0	2,623	511.0	3.00	3.00	3.00	34.07	6.64
Little May	205.3	205.3	205.3	1,775	564.0	2.67	2.67	2.67	23.06	7.33
Topsy May	231.0	231.0	231.0	2,619	420.0	3.00	3.00	3.00	34.02	5.64
Average	225.8	225.8	225.8	2,267.6	482.7	2.93	2.93	2.93	31.41	6.33

Table XI shows the amount of food consumed by each lot during the different periods. The silage consumed by Lot 1 exceeded the silage consumed by Lot 2 by 1 percent; this is the reverse of what took place in the first test. In both the first and second test, 37 percent more soybean hay was consumed than stover. As in the first test, the total amount of grain consumed was greater for Lot 2 by 25.6 percent, and these grains were the most expensive. As in the previous test, the total nutrients consumed was practically the same.

Table XII shows the amount of nutrients consumed daily by each cow. On the average, there was very little difference between the nutrients consumed by the two lots.

TABLE XII: Average daily pounds nutrients consumed, 1909

Name of cow	Protein	Crude fiber	Nitrogen-free extract	Ether extract
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal				
Grace Daw	3.314	5.386	15.254	.973
Bessie Nervilette	2 876	4.430	14.337	.883
May 2nd Pedro	2.716	3.951	12.806	.882
Teeny Gray 2nd	2.720	4.233	13.133	.825
Average	2.906	4.500	13.882	.876
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal				
Lady Thorne 4th	2.881	4 027	13.123	.860
Fair Mahomet	2.977	4.432	13.998	.896
Miami Pride	3 033	4 579	14.443	.916
Little May	2.685	4.108	12.705	.799
Topsy May	3.033	4.469	14.460	.917
Average	2.922	4.323	13.746	.878

Table XIII shows that there is slight difference in the average daily production of milk in favor of Lot 2; this continues until the subsequent period. There is a slight difference in the production of fat in favor of Lot 1; this difference remains practically constant throughout the entire period, showing that the two rations were almost equal in productive value, which agrees with the results in the first test.

TABLE XIII: Average daily production of each cow, 1909.

Name of cow	28 days before test		77 days of test		28 days after test	
	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal						
Grace Daw	35.08	1.070	28.50	.962	28.26	.927
Bessie Nervilette	21 66	1.225	19 59	1.140	17 34	.972
May 2nd Pedro	24.85	1.270	21.58	1.149	19.97	1.004
Teeny Gray 2nd	16.46	.968	14.10	.843	12.97	.749
Average	24.51	1.133	20.94	1.021	19.63	.913
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal						
Lady Thorne 4th	26.91	.800	22.21	.741	18.62	.642
Fair Mahomet	32.50	1.040	27.57	.914	26.40	.864
Miami Pride	29 14	1.275	22.89	1.043	18.59	.823
Little May	16.16	.885	13.80	.839	13.53	.788
Topsy May	26.58	1.422	21.36	1.265	18.92	1.078
Average	26.26	1.084	21.56	.960	19.21	.839
Difference	1.75	.049	.62	.061	.42	.074

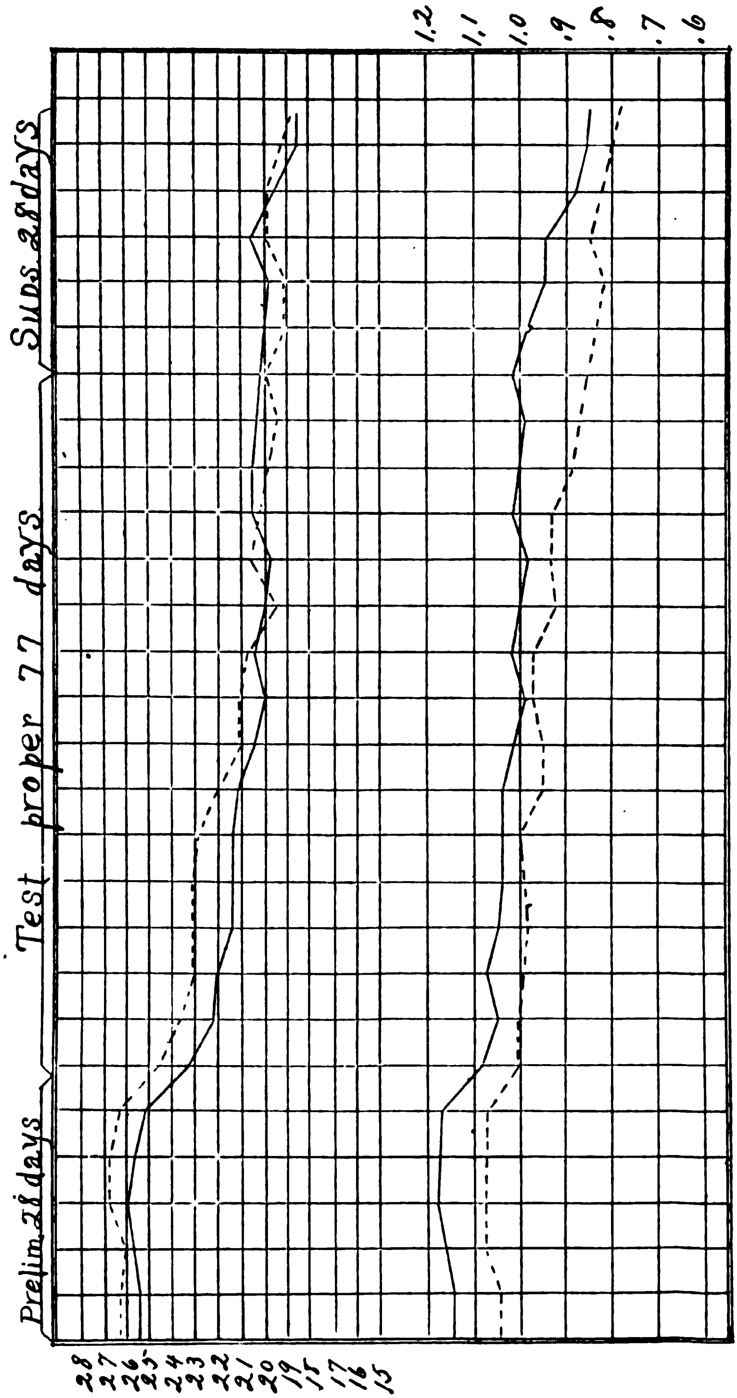
Prelim. 28 days
Test proper 77 days
Subs. 28 days
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Figure 2.

Fig. 2 shows graphically the production of the two lots in the test of 1909. The scale to the left represents pounds of milk daily, and the scale to the right represents pounds of fat daily. The upper solid line represents the average daily production of milk by Lot 1 and the lower solid line represents fat produced daily. The upper broken line represents the average pounds of milk produced daily by Lot 2 and the lower broken line represents the average pounds of butterfat produced daily.

TABLE XIV: Summary of weights, 1909.

Name of cow	Average weight at beginning of test (lbs.)	Average weight, at end of test (lbs.)	Gain or loss (−) (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal			
Grace Daw	1,139 0	1,155.0	16.0
Bessie Nervilette	845.0	862.0	17.0
May 2nd Pedro	842.0	833.0	−9.0
Teeny Gray 2nd	831.0	843.0	12.0
Average	914.2	923.2	9.0
Lot 2: Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal			
Lady Thorne 4th	988.0	1,011.0	23.0
Fair Mahomet	915.0	925.0	10.0
Miami Pride	1,015.0	1,015.0	0.0
Little May	821.0	863.0	42.0
Topsy May	877.0	906.0	29.0
Average	923.2	944.0	20.8

Table XIV shows the summary of the weights of the cows. The value of a ration can not be determined by considering the production of milk only, but the gain or loss in body weight should also be taken into account. The average gain for Lot 1 was 9 lbs. (1-6 pound daily) and that for Lot 2 was 20.8 lbs. (less than ⅓ lb. daily). In this test the grain ration produced the greater gain. Neither lot gained as much as in the first test, though the latter period extended for 17 days longer than the former.

Table XV shows the total amount of products yielded, the total amount of dry matter consumed, and the amount of dry matter required per unit of product. It appears that 5 percent more dry matter was required to produce a unit of product with the grain ration than with the soybean ration. This is a greater difference than in the previous test, but it is a small difference, and it means that the two rations were practically equally efficient.

TABLE XV: Amount of dry matter required to produce a unit of product, 1909.

Name of cow	Milk produced (lbs.)	Butterfat produced (lbs.)	Total dry matter consumed (lbs.)	Dry matter per 100 lbs. of milk (lbs.)	Dry matter per pound butterfat (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal					
Grace Daw	2,194.6	73.766	2,021.68	92.12	27.42
Bessie Nervilette	1,508.5	87..92	1,814 48	120.28	20.67
May 2nd Pedro	1,661.9	88.435	1,642.81	98 85	18.58
Teeny Gray 2nd	1 085.4	64.908	1,693.31	156.00	26.09
Average	1,612.6	78.618	1,793 07	111.19	22.81
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal					
Lady Thorne 4th	1,710.3	57.068	1,694.21	99.05	29.69
Fair Mahomet	2,122.6	70.409	1,806.71	85.11	25.66
Miami Pride	1,762.9	80 290	1,860.31	105.52	23.17
Little May	1,062.4	64.600	1,647.19	155.04	25.50
Topsy May	1,645.0	97.417	1,853.29	122.66	19.02
Average	1,660.6	73.957	1,772.34	106.72	23.96

FINANCIAL STATEMENT

Table XVI gives a financial statement of the results of the test. The difference in the daily cost of feed per cow was less than 1 cent in favor of the soybean ration. The difference in the cost of 100 pounds of milk was a little over 1 cent. The difference in the cost of butterfat was 2.9 cents per pound in favor of the soybean ration.

TABLE XVI. Cost of feeds and value of product, 1909

Name of cow	Cost of product				Value of product			
	Total cost of feed	Average daily cost of feed	Cost per 100 lbs. milk produced	Cost per lb. butterfat produced	Butter fat	Skim-milk	Total	Average daily value of product
Lot 1. Ration during test: corn silage, soybean hay, corn meal, cotton-seed meal								
Grace Daw	$13 07	$ .170	$ .595	$ .178	$18.33	$3.18	$21.51	$ .279
Bessie Nervilette	12.22	.159	.810	.139	21.96	2.13	24 08	.313
May 2nd Pedro	11.42	.148	.687	.129	22 11	2.36	24.47	.318
Teeny Gray 2nd	11.29	.147	1.040	.174	16.23	1.53	17.76	.231
Average	12.00	.156	.783	.155	19.65	2.30	21.95	.285
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal, cotton-seed meal								
Lady Thorne 4th	$ 12.40	$ .161	$ .725	$ .217	$14.27	$2.48	$16.75	$ .218
Fair Mahomet	13.03	.169	.614	.185	17.60	3.08	20.68	.269
Miami Pride	13.50	.175	.766	.168	20 07	2.52	22.59	.293
Little May	11.38	.148	1.071	.183	15.59	1.50	17.09	.222
Topsy May	13.32	.173	.810	.168	24.35	2.32	26.67	.346
Average	12.72	.165	.797	.184	18.37	2.38	20.75	.269

A careful study of these two tests shows that they agree very closely in the results obtained, showing that a large share of the protein can be supplied in soybean hay instead of concentrates, with equal efficiency.

PART II.

PLAN

In view of the results secured through the use of soybean hay as a protein carrier, it was decided to conduct a similar experiment using alfalfa hay as the source of home-grown protein. Alfalfa is destined to become a very important crop in certain sections of Ohio, notably, the western sections. Its production will be attended with greater difficulty in the eastern section, because of the greater lack of lime in the soil. Its enormous yields and high protein content make it especially desirable for dairy purposes. It is possible to combine alfalfa with home-grown feeds in such manner as to secure a balanced ration for reasonably high milk production. If it is possible to get as good results from such rations as from rations containing high priced grain by-products, the cost of milk production will be reduced.*

Each lot consisted of 3 Jerseys and 3 Holsteins. Their ages varied from 2 years, 3 months to 8 years. On the whole the two lots appeared to be exceptionally well balanced; and it is believed that the results should be comparable from this standpoint.

TABLE XVII. Division of cows.

Name of cow	Breed	Age at beginning of test (yrs.)—(mo.)	Date of last calf	Date bred
Lot 1				
La'y May Pedro......	Jersey	2—6	Nov. 5, 1909	Apr. 3, 1910
Little May	"	6—5	Sept. 26, 1909	Jan. 13, 1910
Fair Mahomet........	Holstein	4—9	Nov. 28, 1909	Apr. 14, 1910
Mantee 3rd	"	2—4	Nov 2, 1909	Mar 29, 1910
Lady Gre ta.........	"	2—6	Dec. 20, 1909	Mar 24, 1810
Bessie Lambert......	Jersey	2—3	Jan. 17, 1910	Apr. 29, 1910
Average...........	... .	3—10	Nov 21, 1900	Mar 24, 1910
Lot 2				
Bessie Nervilette.....	Jersey	6—9	Dec. 3, 1909	Apr 15, 1910
Grace Daw 4th	Holstein	2—5	Nov 13, 1909	Apr. 5, 1910
Teeny Gray 2nd......	Jersey	4—11	Oct. 29, 1909	May 25, 1910
Lady Thorne 4th......	Holstein	4—11	Aug 11, 1909	Nov 11, 1909
F. ir Mahomet 1st....	"	2—6	Dec. 26, 1909	May 6, 1910
Lucy May............	Jersey	2—4	Jan. 8, 1910	Apr. 17, 1910
Average..........	....	4—0	Nov. 15, 1909	Mar. 29, 1910

*For information about soybean culture and yields see Circulars 78, 132 and Bul. 237 of the O. A. E. S

The ration supplied Lot 1 consisted of corn meal, corn silage, and alfalfa hay; and that supplied Lot 2 consisted of corn meal, wheat bran, cotton-seed meal, corn silage and corn stover, the nutritive ratio being practically the same. The test proper lasted for 56 days during which time the two lots were on the rations mentioned above. In order to determine their production when on like rations, both lots were fed for a preliminary period of four weeks on the ration prescribed for Lot 1. For four weeks subsequent to the test proper, both lots were fed the ration prescribed for Lot 2.

FEED CONSUMED

TABLE XVIII. Average feed consumed daily during 56 days test

Name of cow	Corn meal (Lbs.)			Corn silage (Lbs.)	Alfalfa hay (Lbs.)
Lot 1					
Lady May Pedro	5.045			27 067	9 978
Little May.	6.973			27.785	11.210
Fair Mahomet.	6.045			30.058	13 330
Mantee 3rd	6.045			30 152	13 446
Lady Gretta	6.000			27 031	12.170
Bessie Lambert	5.000			25.000	9.473
Average	5.931			27.848	11.601
Lot 2	Bran	Corn meal	Cotton-seed meal	Corn silage	Corn stover
Bessie Nervilette	3 563	3 563	3 563	30.625	6.723
Grace Daw 4th	3 000	3 000	3.000	30 357	6.652
Teeny Gray 2nd	3.558	3.558	3 558	30.571	7.138
Lady Thorne 4th	3.000	3.000	3.000	29 393	6.339
Fair Mahomet 1st	3.000	3 000	3.000	30 000	4.183
Lucy May	2.500	2.500	2.500	25 000	2.647
Average	3.105	3.105	3 105	29.324	5.614

Table XVIII shows the average daily feed consumed during the test proper. It will be noted that the average daily grain ration received by Lot 1 was 5.85 pounds and that by Lot 2, 9.31 pounds. This shows over one-third more grain for Lot 2, while Lot 1 consumed twice as much alfalfa hay as Lot 2 consumed stover. There was not a great difference in the total amount of nutrients consumed. The exact figures are shown in the following table.

TABLE XIX. Compositions of average daily rations.

Lbs.	Feed	Dry matter (lbs.)	Protein (lbs.)	Crude fiber (lbs.)	Nitrogen free extract (lbs.)	Ether extract (lbs.)
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay.						
5.9	Corn meal	4.81	.52	.10	3.88	.22
27.8	Corn silage	5.67	.39	1.70	3.11	.13
11.6	Alfalfa hay	10.19	1.60	4.00	3.57	.14
	Total	20.67	2.51	5.80	10.56	.49
Lot 2. Ration during test: Bran, corn meal, cotton-seed meal, corn silage, stover						
3.1	Wheat bran	2.72	.48	.14	1.87	.12
3.1	Corn meal	2.53	.27	.05	2.04	.12
3.1	Cotton-seed meal	2.80	1.25	.28	.85	.21
29.3	Corn silage	5.97	.41	1.79	3.27	.14
5.6	Corn stover	4.27	.30	1.57	2.08	.07
	Total	18.29	2.71	3.83	10.11	.66

Lot 1 consumed less protein and more crude fiber than Lot 2; and from this one would naturally conclude that Lot 1 should produce a little less milk, unless the protein supply in ration 1 was entirely sufficient for their needs, in which case a slight excess was used in ration 2.

PRODUCT RETURNED

TABLE XX. Average daily production of milk and butterfat.

Name of cow	28 days before test		56 days of test		28 days after test	
	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay						
Lady May Pedro	12.9	.74	11.20	.65	10.8	.64
Little May	21.4	1.22	18.20	1.03	16.5	.93
Fair Mahomet	31.8	1.08	32.15	1.03	33.6	1.02
Mantee 3rd	26.7	.87	25.22	.81	22.9	.74
Lady Gretta	30.4	1.2	30.64	.95	29.0	.84
Bessie Lambert	16.8	.84	14.57	.78	13.3	.77
Average	23.4	.96	22.04	.87	21.0	.82
Lot [illegible]. Ration during test: Corn, bran cotton-seed meal, [illegible] silage, stover						
Bessie Nervilette	24.3	1.36	20.48	1.1[illegible]	18.2	1.02
Grace Daw 4th	25.1	.88	23.68	[illegible]	23.3	.71
Teeny Gray 2nd	20.1	1.21	19.12	1.20	16.7	1.03
Lady Thorne 4th	25.0	.74	24.37	.74	27.3	.81
Fair Mahomet 1st	23.1	.77	21.82	.68	18.1	.55
Lucy May	15.4	.90	13.77	.82	11.8	.71
Average	22.1	.98	20.54	.90	19.2	.8[illegible]

Table XX shows the amount of milk and fat produced daily by the individual cows and the average. From this table we observe that Lot 1 produced slightly more milk than Lot 2, while Lot 2 produced slightly more butterfat than Lot 1. This difference in fat is undoubtedly due to the difference in the original percentage of butterfat between the two lots. While there is a difference between the two lots, this difference remains quite constant throughout the three periods, indicating that the two rations were practically equal in efficiency. Though there was little difference in the production of milk and butterfat, there seems to have been more difference in the weight of the animals. It is interesting to note that the lot producing the largest amount of butterfat gained the least in weight.

TABLE XXI. Summary of weights.

Name of cow	Average weight at beginning of test (lbs.)	Average weight at end of test (lbs.)	Loss or gain in weight during test (lbs.)
Lot. 1. Ration during test: Corn meal, corn silage and alfalfa hay.			
Lady May Pedro	791.0	855.0	64.0
Little May	811.0	812.0	31.0
Fair Mahomet	780.0	984.0	4.0
Mantee 3rd	872.0	934.0	62.0
Lady Gretta	938.0	960.0	22.0
Bessie Lambert	675.0	711.0	36.0
Average	844.5	881.0	36.5
Lot 2. Ration during test: Bran, corn, cotton-seed meal, corn silage and stover.			
Bessie Nervilette	884.0	882.0	−2.0
Graco Daw 4th	954.0	968.0	14.0
Teeny Gray 2nd	837.0	840.0	3.0
Lady Thorne 4th	978.0	991.0	13.0
Fair Mahomet 1st	1,008.0	1,003.0	−5.0
Lucy May	757.0	740.0	−17.0
Average	903.0	904.0	1.0

The table shows that Lot 1 gained an average of 36.5 pounds in the 56 days, while Lot 2 gained 1 pound. Every cow gained on the alfalfa ration while 3 gained and 3 lost on the other ration. (Average of 3 days weights.) This would indicate that a little more carbohydrates and fat were given than were required for milk production. This partly explains the difference in the amount of dry matter required to produce a given amount of milk and fat, as shown in the next table. It is also partly explained by the fact that Lot 1 received more crude fiber than did Lot 2.

TABLE XXII. Comparative production based on dry matter

Name of cow	Milk produced (lbs.)	Butterfat produced (lbs.)	Total dry matter consumed (lbs.)	Dry matter per 100 lbs. milk (lbs.)	Dry matter per lb butterfat (lbs.)	Average daily dry matter consumed (lbs.)
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay.						
Lady May Pedro	628.1	36.4	1,030.3	164.3	28.3	18.4
Little May	1,019.2	57 8	1,187.2	116 5	20 5	21 2
Fair Mahomet	1,800.6	57.7	1,275.1	70.8	22.1	22.8
Mantee 3rd	1,412.4	45.4	1,281.8	90.8	28.3	22 9
Lady Gretta	1,715.8	53.1	1,181.4	68 9	22 2	21.1
Bessie Lambert	812.8	43.6	979.8	120.6	22.5	17.5
Average	1,231.3	49.0	1,155.9	105.3	24.0	20.6
Lot 2. Ration during test: Bran, corn, cotton-seed meal, corn silage, corn stover						
Bessie Nervilette	1,147 3	66.0	1,155.3	100.7	17.5	20.6
Grace Daw 4th	1,326.6	46.1	1,030.3	77.6	22.4	18.4
Teeny Gray 2nd	1,071.1	67.4	1,172.0	109.4	17 4	20.9
Lady Thorne 4th	1,365.2	41.6	1,043.2	76.4	25.0	18.6
Fair Mahomet 1st	1,222.0	38.1	957.9	78.4	25 2	17.1
Lucy May	771.6	46.0	762.4	98.8	16.6	13.6
Average	1,150.6	50.9	1,020.2	90.2	20.7	18.2

The above table shows that Lot 1 consumed 16.6 percent more dry matter per 100 pounds of milk, and 19.3 percent more per pound butterfat. The economy of a ration depends on its cost as well as on its efficiency. In the following table the costs are set forth; but, these costs apply only when the prices given on page 128 are used.

TABLE XXIII. Cost of product

Name of cow	Total cost of feed	Average daily cost of feed	Cost to produce 100 lbs. of milk	Cost to produce 1 lb. of butterfat
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay.				
Lady May Pedro	$ 7 90	$ .14	$1.26	$ .22
Little May	9.38	.17	.92	.16
Fair Mahomet	9.64	.17	.54	.17
Mantee 3rd	9.68	.17	.69	.21
Lady Gretta	9.04	.16	.53	.17
Bessie Lambert	7.55	.13	.93	.17
Average	8.86	.16	.81	.18
Lot 2. Ration during test: Bran, corn meal, cotton-seed meal, corn silage, stover.				
Bessie Nervilette	$10.71	$ .19	$ .93	$ .16
Grace Daw 4th	9.51	.17	.72	.21
Teeny Gray 2nd	10.74	.19	1.00	.16
Lady Thorne 4th	9.40	.17	.69	.23
Fair Mahomet 1st	9 20	.16	.75	.24
Lucy May	7.57	.14	.98	.16
Average	9.53	.17	.85	.19

It will be noted that the average difference in cost per 100 pounds of milk was 4 cents, and per pound butterfat was 1 cent in favor of Lot 1 on the alfalfa ration. It is interesting to note from the following table that the cost of the feed equaled 61 percent of the value of the product in Lot 1 and 68 percent in Lot 2, leaving 39 and 32 percent to be accounted for by labor, taxes, depreciation, interest, profit, insurance, etc.

TABLE XXIV. Value of product on butter basis.

Name of cow	Value of butterfat	Value of Skim milk	Total value of product	Average daily value of product
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay				
Lady May Pedro	$ 9.10	$ .89	$ 9.99	$ .18
Little May	14.45	1.44	15.89	.28
Fair Mahomet	14.43	2.61	17 04	.30
Mantee 3rd	11.34	2.05	13.39	.24
Lady Gretta	13 28	2.49	15.77	.28
Bessie Lambert	10 90	1.15	12.05	.22
Average	12.25	1.77	14.02	.25
Lot 2. Ration during test: Corn, bran, cotton-seed meal, corn silage, stover.				
Bessie Nervilette	$16.50	$1.62	$18.12	$.32
Grace Daw 4th	11.52	1.92	13.44	.24
Teeny Gray 2nd	16.85	1 51	18.36	.33
Lady Thorne 4th	10 40	1.99	12.39	.22
Fair Mahomet 1st	9.51	1.78	11.29	.20
Lucy May	11.49	1.09	12.58	.22
Average	12.71	1.65	14.36	.26

CONCLUSIONS

The above considerations show that alfalfa as well as soybeans can replace much of the high priced protein concentrates. Other legumes will answer the same purpose in a lesser degree. Clover is especially valuable in this respect, though not as good results should be expected per ton as with the soybean or alfalfa hay.

From the above it is evident that the extensive use of milling by-products or other commercial feeds is not necessary in milk production where legumes can be grown well. However, it often proves profitable to use such feeds and unless the use of home-grown feeds will yield as great a profit, all things considered, the commercial feeds should be used.

There are other factors than simply the efficiency of the ration which should be taken into consideration in figuring profits. Some of the factors are: Adaptability of the farm for growing the feeds desired; distance crops or feeds must be hauled to or from the market; the suitability of legumes for desired rotations; relative

value of fertilizing constituents of feeds purchased or produced; effect of legumes on the soil; the investment required in the purchase of grains or mill feeds; other and possibly more economical means of handling the soybean plant, and the consideration of market conditions.

The investment required when one depends on grains and mill feeds for protein is, perhaps, of minor importance. It is true, however, that on many occasions money with which to purchase feeds is not available, and also that the use of money during the time the feed is being consumed is of sufficient importance to warrant consideration.

The most economical way to handle the soybean plant is to many an unsettled question. On account of its nature of growth, the stem of the plant is quite woody and the cattle do not eat the stems readily. The time and manner of harvesting will control this point to a considerable extent. The practice of putting soybeans into the silo with corn silage is growing in some places, though it makes a strongly flavored silage. This plan is, perhaps, most popular at present; and on account of the difficulty in curing it for hay seems to be the best method of handling the soybean plant. However, the use of the soybean in the form of hay is altogether practical and is preferred by some.

An intimate knowledge of all local conditions, which is possible only to the man on the ground, is necessary if the most economical selections of feeds are to be made.

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Special recognition is due Mr. B. E. Carmichael, Chief of the Department of Animal Husbandry, for his valuable assistance in planning and directing much of the work reported in this publication, and to Mr. C. C. Hayden, present head of the Department of Dairy Husbandry, who assisted in the final arrangement of material.

CORRECTIONS TO CIRCULAR 136

On page 124 of Circular 136, directions are given for mixing fly repellants. It seems that two errors have been made. In formula 1, not over one-half pint of the acid should be used. This formula is hardly advisable since there is such great variation in the purity of carbolic acid designated as "crude."

In formula 2, the word *parts* should read *pints*. For formula 1, substitute 100 parts fish oil, 50 parts oil of tar (not tar) and 1 part of crude carbolic acid.

SUBSTITUTES FOR CORN IN RATIONS FOR FATTENING SWINE

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JANUARY, 1914

BULLETIN 268

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BULLETIN

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FORAGE CROPS: ANNUAL GRASSES AND ROOTS

C. G. WILLIAMS AND F. A. WELTON

The word "forage" is used in this bulletin to include those farm crops which are grown for the feeding of livestock and are fed as a whole, either green or dry. For instance: Corn, when it is husked and fed separately as grain and stover, is not considered a forage crop; but when the whole plant is fed as one feed, whether green, dry, or as silage, it is classed as a forage crop.

Our forage crops are found in three principal groups: Grasses, legumes and roots. This bulletin will treat the more valuable annual grasses and roots which have been tested at this Station. The perennial grasses are treated in Bulletin 225; soybeans and cowpeas in Bulletin 237 and, in a future publication, the clovers and some other legumes will be discussed.

In forage crops, as well as in grain crops, corn may properly head the list.

VARIETY TESTS OF CORN FOR THE SILO

For the past ten years the Ohio Station has been testing a number of different varieties of corn for use as silage. It has had difficulty, some seasons, in securing some of the varieties with which work was started and accordingly is able to report work with eight varieties for 5 consecutive seasons only.

TABLE I. Varieties of corn for the silo

Variety	Tons of corn per acre						Percent				Pounds per acre				
	1913	1912	1911	1910	1909	5-year av.	Protein	Crude fiber	Nitrogen free extract	Fat	Protein	Crude fiber	Nitrogen free extract	Fat	Total nutrients
Blue Ridge—Virginia	12.55	20.71	15.52	7.78	15.82	14.48	1.96	6.20	16.23	.50	567.6	1795.5	4700.2	144.8	7389.1
Hickory King—Virginia	12.34	18.43	13.70	7.15	16.56	13.64	2.00	5.50	15.10	.44	545.6	1500.4	4119.3	120.0	6435.3
Pike Co. White—Ohio (U. S. 77)	12.28	16.26	15.85	7.13	12.61	12.83	1.82	5.07	15.56	.39	467.0	1301.0	3992.7	100.0	5985.7
Boone Co. White—Md., (U. S. 119)	12.43	16.26	15.74	6.83	13.43	12.94	2.07	5.78	16.29	.46	535.7	1495.8	4215.8	119.0	6515.0
Boone Co. White—Tenn., (U. S. 138)	12.96	18.14	15.39	6.85	16.17	13.90	1.89	5.65	14.03	.34	525.4	1570.7	3900.3	94.5	6209.0
Boone Co. White—Ohio	10.88	16.98	15.65	8.47	13.01	13.00	2.06	5.73	16.43	.50	535.6	1489.8	4271.8	130.0	6589.7
Darke Co. Mammoth—Ohio	7.26	15.04	13.87	4.86	14.04	11.01	2.28	5.47	18.75	.55	502.0	1204.5	4128.7	121.1	6107.7
Leaming—Ohio	8.43	11.48	12.22	5.09	10.46	9.54	2.43	6.40	20.34	.69	463.6	1221.1	3880.8	131.7	5861.8

Of the varieties reported upon, the Blue Ridge comes from old Virginia. It is a white dent corn with a white cob and is grown quite extensively by the dairymen of northeastern Ohio for silage uses.

The Hickory King also comes from Virginia, though it is grown quite extensively further south as a field corn.

The Pike County White (U. S. 77) is grown extensively in Pike County, Ohio, where it is known as "Woodburn's White."

Three strains of the Boone County White have been used. Two of them have been secured each year through the U. S. Department of Agriculture; one from Maryland (U. S. 119), the other from Tennessee (U. S. 138). The third strain has been secured new each year from southern Ohio.

The Darke County Mammoth is a popular variety of yellow dent field corn from Darke County, Ohio. It is considerably earlier than the above mentioned varieties and usually matures at Wooster.

The Leaming used in this test is an early strain from the son of the originator of this variety in Clinton County, Ohio.

The yields are given in tons of green corn as cut and weighed into the silo. There is no very marked variation in the maturity of the different varieties save in the case of the last two. The Darke County Mammoth and the Leaming being earlier varieties naturally carried less water than the others and their weight per acre is much lower.

For four of the five seasons reported, each variety was sampled the day it was cut and put in the silo and an analysis made by the Department of Chemistry. The method of sampling was to choose a number of representative plants of each variety. These plants were separated into fodder, grain and cob and each part was weighed and analyzed by itself. It is believed that the nutrients can be determined with greater accuracy in this way than by sampling the chopped corn at random. The average analyses of the different varieties for the several seasons appear in the columns giving the percentage composition. The pounds per acre of the different nutrients, as well as the total nutrients per acre, are computed from the 5-year average yield per acre and the percentage composition.

It will be noted that the varieties which might be classed as "field" corn (The Darke Mammoth and the Leaming), i. e., varieties adapted to the growing of grain because they may be expected to come to complete maturity, do not furnish as large an amount of nutrients per acre as the larger and somewhat later varieties. While a ton of this field corn silage will carry much more nutrients

than a ton of the larger, or so-called "silage" corn, an *acre* of it will furnish less nutrients. Attention should be called to the fact that considerably more water will have to be handled with the larger, or silage corn.

The Station does not recommend any particular variety or type of corn for the silo. It endeavors to report its findings impartially, realizing that the needs of individual dairymen differ. In intensive dairying, where it is a problem to secure enough roughage, the silage corn will likely prove more satisfactory. In the corn belt sections where the problem is to take care of the corn crop, the field corn will doubtless be more satisfactory. Silage made from the latter will not call for the purchase of as much concentrates to feed with it as the former.

While the above figures show more nutrients per acre from the later varieties, the mistake should not be made that mere lateness and immaturity are in themselves advantageous. It should be stated that the closer any variety approaches maturity the more nutrients *that variety* will carry. Accordingly the silage varieties should be planted as early as is safe and be left to come as close to maturity as possible. It is undoubtedly possible to go to extremes in the use of large and late varieties of corn for the silo, though it would seem that one might wisely grow varieties somewhat larger and later than he would feel safe in growing for grain only.

Two varieties of corn have been grown in this silage test for the full period of 10 years. One of them, the Leaming, of the field corn type; the other, the Blue Ridge, of the silage type. The latter was not known under the name of Blue Ridge at the beginning of this test, though it has always been secured from the same source and is the same corn.

The yields per acre are as follows:

TABLE II. The Leaming vs. the Blue Ridge

Variety	Tons of corn per acre										10-yr. av.
	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	
Blue Ridge.	12.55	20.71	15.52	7.78	15.82	12.80	15.42	15.25	15.25	15.86	14.79
Leaming...	8.43	11.48	12.22	5.09	10.46	7.30	10.55	10.57	11.60	16.45	10.41

The large yield of Leaming corn for 1904 was due to the fact that the Leaming used that year was a late western strain. It would, perhaps, be fairer not to average it in, as for the Ohio Station conditions it would rank with the silage, rather than with the field type. The 9-year average of the Leaming is 9.74 tons per acre.

In this variety test the corn was planted in hills in order that a perfect stand might be secured by thick planting, then thinned to a uniform stand when the corn was 6 to 8 inches high. In field work the Station drills its silage corn.

Fig. 1. Harvesting silage corn.

THICKNESS OF PLANTING CORN FOR THE SILO

This Station has been conducting experiments the past 5 years to determine if possible the proper distance apart to drop kernels in drilling corn for the silo. Four different distances have been tested, viz., 4, 6, 10 and 12 inches. A one-horse corn drill with brush feed has been used throughout the test and quite uniform dropping has been secured. The results of this test are given in Table III.

It will be noted that the differences in yield of corn per acre vary widely with the season. In 1909 and 1912 the 4-inch drilling led by a wide margin, while in 1911 and 1913 it was a little behind the 6-inch, and but slightly ahead of the 10-inch. In four of the 5 years the 12-inch planting has given the lowest yield of all.

It is of interest to compare the amount of rainfall for the months of June, July and August for the 5 seasons. It is apparent that it is during the seasons of excessive rainfall (1909 and 1912) that the 4-inch plantings make the large yields. In seasons when the rainfall is short or moderate the lead over the 12-inch planting is less than 1 ton per acre on the average. In so far as tons per acre are concerned the 5-year average yield drops quite regularly from the 4-inch to the 12-inch planting.

TABLE III. Thickness of planting corn for the silo. Variety: Blue Ridge

Kernels dropped every:	Tons of corn per acre						Average percent of				Pounds per acre				
	1913	1912	1911	1910	1909	5-yr. av.	Protein	Crude fiber	Nitrogen free extract	Fat	Protein	Crude fiber	Nitrogen free extract	Fat	Total nutrients
4 inches	13.47	21.25	14.88	9.57	19.53	15.74	1.58	7.03	15.11	.32	497.4	2213.0	4756.6	100.7	7693.6
6 inches	13.87	19.68	15.10	9.18	13.53	14.27	1.48	5.73	12.28	.27	422.4	1635.3	3504.7	77.1	5735.9
10 inches	13.18	17.20	14.68	8.50	14.11	13.53	1.71	5.78	13.47	.34	462.7	1564.1	3645.0	92.0	5878.8
12 inches	12.73	16.17	13.78	8.53	13.15	12.87	1.80	5.98	13.00	.31	463.3	1539.3	3346.2	79.8	5528.3

Comparative rainfall

	1913	1912	1911	1910	1909
June...........	0.97	2.21	3.78	2.57	6.44
July............	4.07	7.46	3.36	1.12	4.05
August.........	4.75	7.32	5.19	0.95	5.21
Total..........	9.79	16.99	12.33	4.64	15.70

As in the variety tests, chemical analyses have been made of each lot of corn for 4 of the 5 seasons. The average percentage of nutrients is indicated in the above table and the total pounds of nutrients per acre, based upon these percentages and the 5-year average yield of corn. The thickest planting—the 4-inch—leads in total nutrients, with the 10-inch second, the 6-inch third and the 12-inch fourth.

While these figures favor the 4-inch planting, there is one very serious disadvantage in this very thick planting which should be mentioned, viz., the plants do not stand up well. They are so slender that they lodge badly, thus making it difficult, both to cut the corn, even with a harvester, and to handle the bundles after they are cut. It is quite probable that, one year with another, 10-inch planting will prove most satisfactory.

This Station has not gathered any data upon the use of corn as a dry forage. The data furnished in Table III should, however, be applicable. Since the finer stalks will be consumed more closely than the coarser, it would doubtless be an advantage to plant corn thicker for dry feeding than for silage.

SORGHUMS

Among the annual forage grasses, sorghum probably ranks next to corn. Three types are usually recognized: Saccharine, non-saccharine and broom-corn.

On account of the dryness of its stems, broom-corn is of little or no value as a forage plant. It is grown almost exclusively for the production of seed and brush—a trade term for the material from which brooms are made—and consequently will not be discussed in this bulletin.

Saccharine sorghum is characterized by an abundance of sweet juice in the stalks of the plants. Formerly it was grown chiefly for the production of syrup but now it is utilized largely as forage, it being the best of all the sorghums for that purpose. Agriculturally, the term "sorghum" is often restricted to this division alone.

The stalks of non-saccharine sorghum possess a small amount of juice and, while sweet in some, in other varieties it is more or less sour.

The members of this division are grown chiefly for grain, and for that purpose they are of great value in semi-arid regions where the rainfall is not sufficient for the proper development of corn; but in humid climates, like that of Ohio, they are of minor value for the production of grain and are utilized to a limited extent only as forage.

For the past two years cane has been included in the Station's variety silage test. That it is hardly equal to corn in the production of silage under Ohio conditions is shown by Table IV, only two varieties—Darke County Mammoth and Leaming—falling below it in yield. The relatively high yields for 1912 may be attributed to excessive rainfall and to fertile soil, the test that year being conducted on an alfalfa sod.

TABLE IV Corn vs. cane silage.

Variety	Tons per acre		
	1912	1913	2-year average
Blue Ridge—Virginia	20.71	12.55	16.63
Hickory King—Virginia	18.43	12.34	15.38
Pike County White—O. (U. S. 77)	16.26	12.28	14.27
Boone County White—Md. (U. S. 119)	16.26	12.43	14.34
Boone County White—Tenn. (U. S. 138)	18.14	12.96	15.55
Boone County White—O,	16.98	10.88	13.93
Darke County Mammoth—O	15.04	7.26	11.15
Leaming—O	11.48	8.43	9.95
Cane	13.91	11.95	12.93

From time to time, for the past 13 years, a few of the older and more common varieties of sorghum, both saccharine and non-saccharine, have been grown on the Station farm, and from the yields of green forage, which are tabulated in Table V, it is possible to formulate some idea as to their relative value when grown under Ohio conditions.

TABLE V. Sorghum: Tons of green forage per acre.

Year	Variety					
	Saccharine		Non-saccharine			
			Kafir		Durra	
	Amber	Orange	Red	White	Yellow milo	White
1901	11.7	....	9.7	10.7	7.6	...
1902	13.2	....	10.4	10.9	4.9	5.8
1903	8.3	12.7	....	....	8.9	3.9
1905	13.4	17.2	10.1	12.8	...	...
1911	16.2	....	....	12.1	8.3	...
1912	6.2	10.7	5.9	6.9	4.9	..
1913	11.9	15.2	9.8	10.6	7.9	..
Average	11.6	13.9	9.2	10.7	7.1	4.8

Though there are several varieties of saccharine sorghum, only two—Amber and Orange—have been grown at Wooster.

Amber: On the Station farm, Amber attains a height of 7 to 10 feet; has a moderate number of leaves and matures in ample time for the production of forage of good quality. The seed head or panicle is black and more or less open. (Fig. 2.)

Orange: As compared with Amber the Orange is taller, coarser, more leafy, later in maturity and in those years in which both have been grown, the yield of Orange has exceeded that of Amber—the excess ranging from 2.5 to 4.5 tons per acre. The coarseness of the stalk renders it more difficult to cure and hence less desirable than Amber as cured forage. The seed head or panicle is more compact and as it approaches maturity it takes on an orange color, hence the variety name. The greatest usefulness of this variety in Ohio is in the central and southern parts of the state. (Fig. 3.)

Fig. 2. Amber cane.

Non-saccharine sorghum embraces several divisions, the most common, and the only ones, representatives of which have been grown on the Station farm, are Kafir and Durra;[1] the former being characterized chiefly by erect, the latter by recurved heads.

Kafirs: In appearance the chief difference in the varieties of kafir is in color of seed and hull. At this Station only two varieties have been grown—Red and White—these having red and white seeds, respectively. While the Red grows taller (its height averaging 6 to 7 feet), and matures somewhat later than the White, it is more slender and at this Station has yielded a trifle less forage, though the difference is not significant. (Figs. 4 and 5.)

Durras: Of the durra group the variety of most importance which has been tested at this Station is Yellow milo or Milo.

[1]Among other renderings are such as dura, durrah, durrha, dourah and doura.

Compared with the kafirs it matures earlier and yields less forage but in the production of grain it is said to excel all the other sorghums. (Fig. 6.)

White durra, sometimes called "Jerusalem corn" is a durra of minor importance, which when grown on the Station farm several years ago, attained a height of 3 to 5 feet and yielded as an average of two years at the rate of 4.8 tons of green forage per acre.

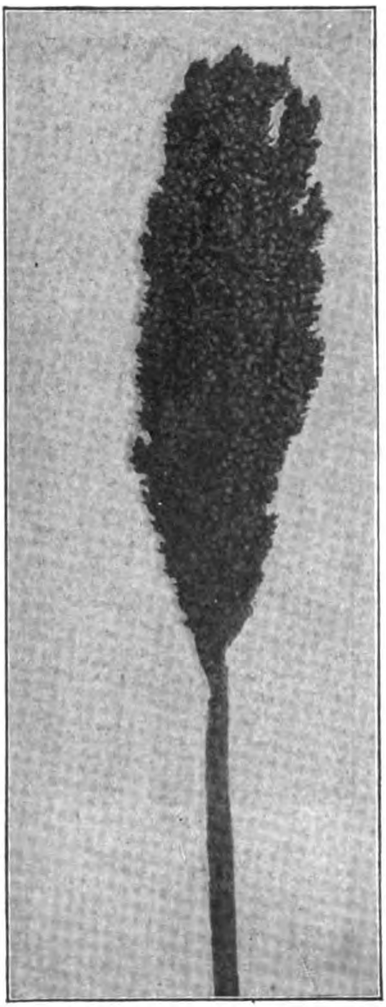

Fig. 3. Orange cane.

Feterita, another member of the durra group and a rather recent introduction from Egypt was grown on the Station farm one year, 1912, and of dry forage it yielded a trifle more than the German millet (one of the best) and considerably less than such sorghums as Amber and Orange cane.

Teosinte: Though belonging to a different species (Euchlaena mexicana), teosinte is so similar to sorghum in its cultural requirements that mention of it may be made here. It is a great stooler and in appearance resembles Indian corn.

In the South, on rich soil, where seasons are long and hot, and where there is an abundance of rainfall—conditions essential for its proper development—it is said to grow 10 to 12 feet high and to yield as high as 50 tons per acre of green forage which is highly prized both for soiling and for silage.

As a source of succulent feed in Ohio it is inferior to both corn and sorghum. On the Station farm it usually attains a height of about 5 feet.

CULTURE OF SORGHUM

Soil: The soil requirements for sorghum are much the same as for corn. On rich land, or with the liberal use of fertilizers on poor land, the yields are increased in the same proportion as are those of corn.

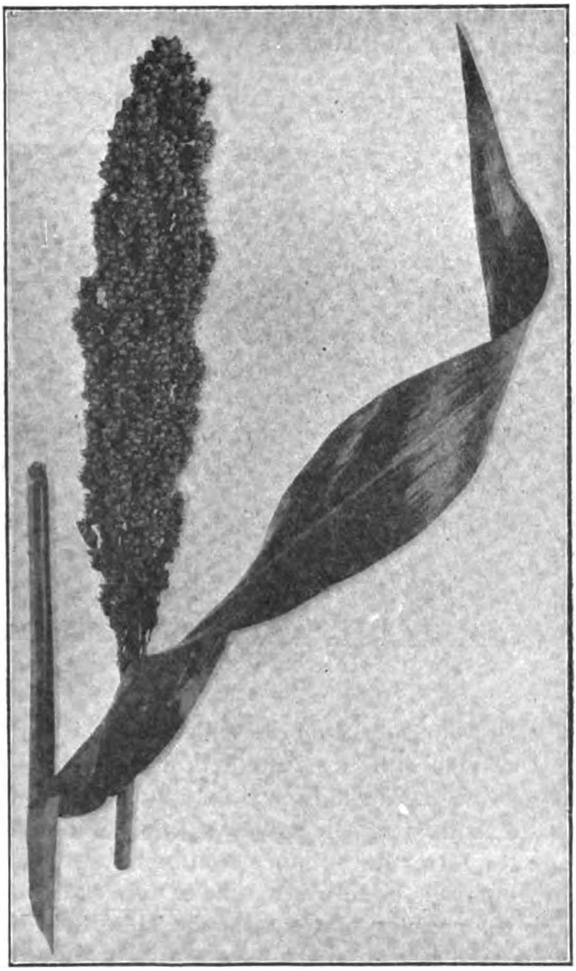

Fig. 4. Red kafir.

Since it is rather shallow rooted, and since it makes its growth in a comparatively short length of time it seems to exhaust, at least temporarily, the available plant food in the surface soil, hence its reputation of being "hard on the land."

Seed bed: The preparation of the seed bed is similar to that for corn. However, since the growth of the young plants, especially for the first few weeks, is very slow, a seed bed strictly clean, well packed and in good tilth, is desirable, else the young plants may be overwhelmed with weeds.

Seeding: In order to encourage a more rapid growth, seeding is best deferred until the ground is thoroughly warm, which, in the latitude of Wooster, is about June 1.

Fig. 5. White kafir.

Sorghum may be broadcasted or drilled solid, using about 1 bushel per acre, thus producing quite a fine quality of hay, or it may be drilled in rows, 36 to 42 inches apart, using 8 to 15 pounds of seed per acre and cultivating the same as corn. When wanted for soiling or silage the latter is the more common method.

The seeding may be done by the use of special plates in the corn planter, or the regular plates may be adapted, if necessary, by filling the holes with lead and subsequently boring new ones of the desired size. By stopping part of the hoes, a grain drill may be used.

Cultivation: During the period of its comparatively slow growth, especially if the sorghum is drilled solid, the use of a light harrow or weeder is important. It is advisable to drive parallel with, rather than across the rows. Later cultivation should be the same as for corn—frequent but shallow.

HARVESTING

Silage or fodder: For silage, sorghum is best harvested when the seed is in the dough stage, using an ordinary corn binder. A more bitter silage results from earlier cutting and loss of nutrition from later cutting, as mature seed may pass through animals undigested. Its tendency to ferment renders it more difficult to keep than corn, but when well preserved its feeding value is not much inferior to that of corn.

If, instead of silage, it is utilized as dry forage, the small bundles may be set up and securely tied in moderate sized shocks and fed from the field; or when it is dry—say 4 or 5 weeks after cutting—it may be hauled to the barn and stacked.

Having finer as well as more juicy and palatable stems, the dry forage is equal, if not superior to corn.

Soiling: For soiling, sorghum may be cut at any time after it is large enough to handle nicely, though to best advantage from the time it blooms until towards maturity. As a soiling crop, sorghum is consumed more closely than corn and its resistance to drought makes it a valuable crop for the production of succulent feed during the hot, dry months of summer.

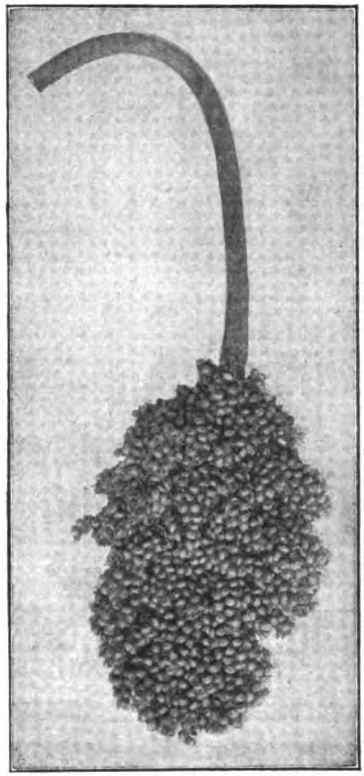

Fig. 6. Yellow milo. Three-eighths natural size

Hay: For hay, sorghum may be cut at any time after heading, though for best quality it should be harvested shortly after blooming. A mowing machine may be used, setting it to cut as high as possible. On account of the succulence of the stems it should be allowed to lie in the swath for several days before cocking and should be thoroughly dry before stacking.

It may be expected to yield from 4 to 8 tons of dry forage per acre.

Pasture: Some danger attends the pasturing of sorghum due to the development of hydrocyanic acid when the growth is checked as by drought or frost. After poisonous sorghum is cut and allowed to wilt, it is said to be fed with little or no danger. Bloat sometimes results from pasturing cattle or sheep on sorghum.

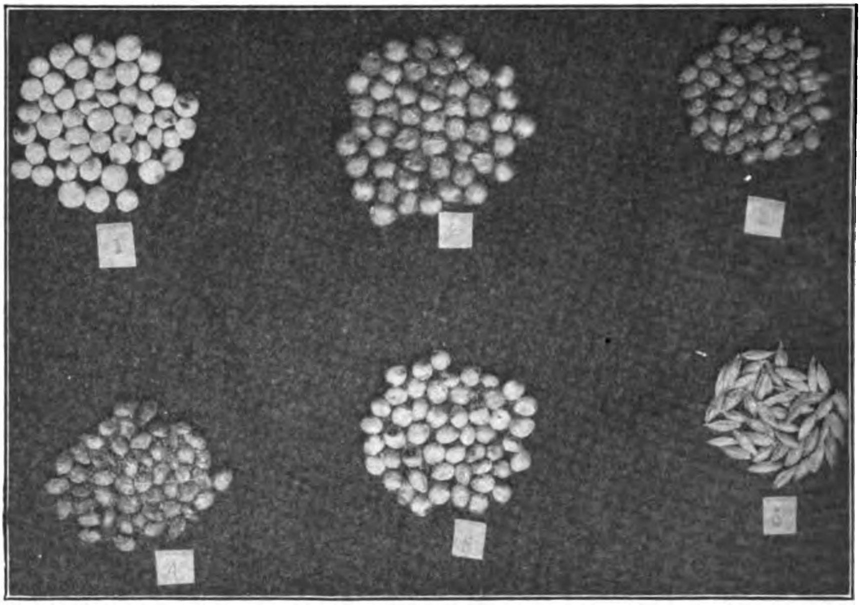

Fig.7. Sorghum seeds. (1) Feterita, (2) Milo, (3) Amber, (4) Orange, (5) White kafir, (6) Sudan grass (unhulled). Natural size.

SORGHUM AND COWPEAS

To get a better balanced feed, cowpeas are sometimes grown with sorghum, either seeding in rows and cultivating, using about 1 peck of each per acre, or seeding solid, using about 4 pecks of cowpeas and 3 pecks of sorghum per acre, After cutting, this mixture should lie in the swath a few days and then be put into cocks where it may remain for a considerable length of time.

At this Station, this combination has been tried several times, but always with unsatisfactory results. The sorghum, though fine, and attaining a height of 4 or 5 feet only, has usually choked out nearly all of the cowpeas, the few remaining being small and of little consequence. A mixture of Amber cane and New Era cowpeas yielded in 1911 and 1913, 6.8 and 14.8 tons respectively of green forage per acre.

MILLETS

The millets constitute another group of valuable forage crops. This is a general term applied to a great variety of cereal and forage grasses, differing widely botanically, but having this in common: All are rapid growing annuals, useful either as green or dry forage, and thriving best in midsummer.

USES

Millet is not usually looked upon as a regular staple crop, occupying a definite place in a fixed rotation, but rather as a substitute or emergency (catch) crop; one to be used in case of failure of clover or alfalfa or in case of the destruction by hail or otherwise of some crop like corn or potatoes.

Often, however, it is seeded not as the result of some seasonal catastrophe, but on account of its adaptation to some particular end. In the case of more intensive farming where two crops per year are desired, it is frequently seeded after the removal of a crop of rye or oats and pea hay. It enjoys quite a reputation as a weed eradicator and under favorable conditions as regards climate and soil, few weeds are able to cope successfully with a thrifty crop of millet. For this purpose it is second only to a summer fallow.

Under Ohio conditions millet is utilized almost exclusively as forage; largely as hay, but to a small extent also as a silage or soiling crop.

In some sections certain varieties are grown for the production of seed.

VARIETIES

A common grouping of the more familiar sorts is foxtail (Chaetochloa italica), broom corn (Panicum miliaceum) and barnyard (Panicum crus-galli).

Representative varieties of all these divisions have been grown by the Ohio Station in a small way, the results of which are reported in Table VI in terms of dry forage or hay.

TABLE VI. Millet: Tons of dry forage per acre.

Group	Variety	Year							
		1904	1905	1908	1909	1911	1912	1913	Av.
Foxtail	Hungarian	3.9	3.4	2.6	2.8	...	2.2	1.9	2.8
	German	5.1	6 1	...	4.8	6 6	3.5	4 6	5.1
	Red Siberian	3.8	3.0	...	3.4	3.9	2.1	3.0	3.2
Broom corn	Broom corn	...	...	.	...	5.4	2.3	1 9	3.2
	White French	5.1	4.4	2.6	2.4	4.7	2.3	1.5	3.3
	Early Fortune	...	...	...	...	0.6	2.0	1.5	1.4
	Black Voronezh	...	...	...	...	0.9	2.2	...	1.5
Barnyard	Japan	6.4	5.9	3 8	6.3	9.2	4.5	4.6	5.8
	Sudan Grass	...	...	...	...	...	3.9	4.3	4.1

Foxtail Millets: For Ohio conditions the most useful group of millets is the foxtail—characterized by an inflorescence or head of a single spike—and the varieties most highly prized are the Hungarian and German. For land in a poor state of fertility, or on richer land in the northern part of the state where the seasons are comparatively short, the Hungarian is preferable to the German, the latter being specially adapted to long seasons and to rich, river bottom land.

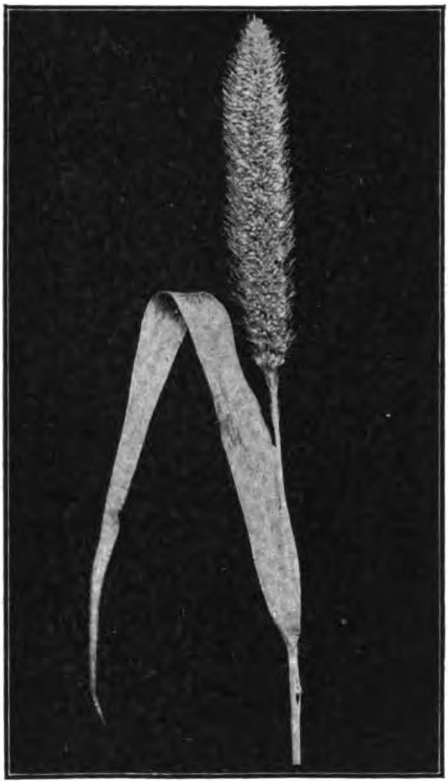

Fig. 8. Hungarian millet. Two-thirds natural size.

The Hungarian millet, or grass, as it is sometimes called, produces from each seed several slender and more or less branched stems upon which are borne rather narrow, dark green leaves and a short, nearly erect, bristly, compact and dark purple head. (Fig. 8.) The seeds are in part purple and in part yellow, the color of the latter possibly being due to immaturity.

The German is a rather coarse, vigorous growing variety, usually producing but one stem from each seed and that not branched. The leaves are somewhat short and broad and the nodding head consisting of clustered branches armed with purplish awns, may be an inch in diameter, 6 to 10 inches long, and bears small yellow seeds. (Fig. 9.)

The Red Siberian is somewhat earlier than the German. As it approaches maturity the heads take on a golden tinge. The color of seeds is a mixture of red and yellow, red predominating.

Broom corn millets: In this group of millets the head is a panicle like that of broom corn, hence the name. (Fig. 10.) They are grown for both seed and forage, chiefly seed, but in Ohio, and even in the United States, their culture is not general, it being restricted

largely to Europe. However, in the northwest, in hot, dry seasons, these millets are frequently seeded as a substitute for corn, for the feeding of hogs, hence the common appelation of "hog millets."

Compared with the foxtail group, the broom corn millets are usually shorter, coarser and seeds are larger and of more varied color—white, yellow, red or nearly black.

Of the varieties of this group tested at this Station, the Broom corn and White French are the most useful. In appearance and habit of growth these two varieties are quite similar but in color of seeds they differ; the Broom corn having yellow; the White French, white seeds.

The Early Fortune and Black Voronezh are smaller and earlier forms and, in Ohio at least, are quite inferior to either the Broom corn or White French. The Early Fortune has purplish hulls with yellow seeds; the Black Voronezh white hulls and blackish seed.

Barnyard millet: This is another name applied to the common barnyard grass—a plant of quite universal distribution and of varied size, form and color in different sections of the country. (Fig. 11.)

The most useful strain of this species—a variety often advertised in seed catalogues as "Billion Dollar Grass"—is one

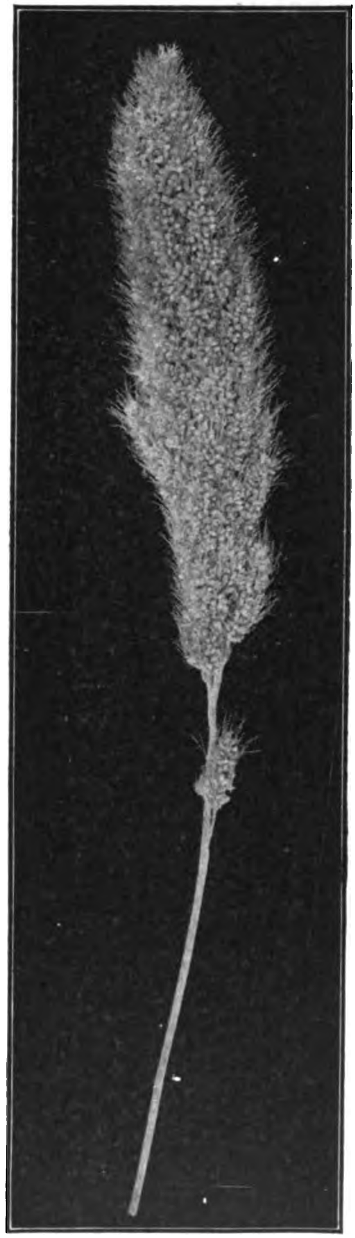

Fig. 9. German millet. Two-thirds natural size.

imported several years ago from Japan by the Massachusetts Experiment Station. According to the findings of that institution it may be regarded as useful for silage and soiling, but unsatisfactory for hay.

While this millet has surpassed in yield of dry forage all the other varieties tested at this Station, the quality of the hay is such, at least under Ohio conditions, that it cannot be recommended in preference to the members of the foxtail group.

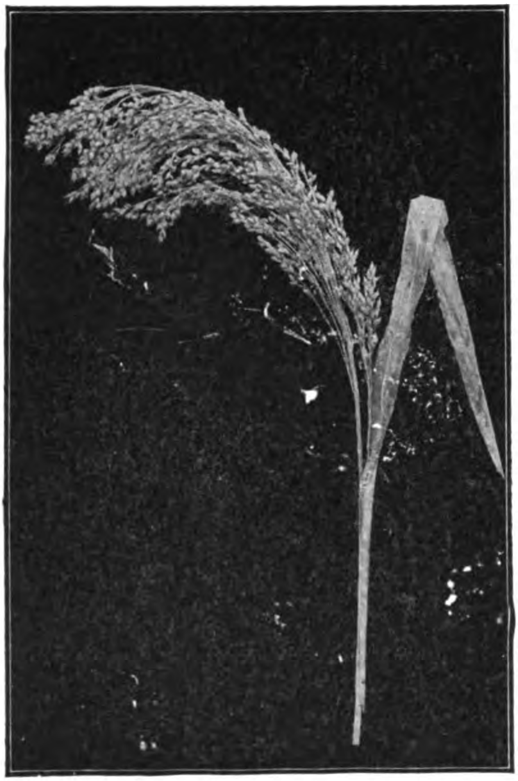

Fig. 10. Broom corn millet. One-third natural size.

Pearl millet: Though technically not a millet, the coarse annual grass bearing cylindrical spikes, 6 to 12 inches long, resembling that of the cat-tail flag, is commonly spoken of as Pearl or Cat-tail millet, (Pennisetum spicatum.)

It suckers freely, and in the South, where length of season permits of two or more cuttings, it is highly prized as a soiling crop, yielding, it is said, as high as 40 tons of green or 16 tons of dry forage per acre.

In Ohio the seasons are too short for its full development. On the Station farm it attains a height of 2 to 9 ft., but usually fails to come into full head.

Pencilaria, Horse millet and Mand's Wonder are a few of the many names under which it is frequently sold.

Sudan Grass: For the past two years, Sudan grass, a comparatively new introduction received from Prof. C. V. Piper, of the Bureau of Plant Industry, U. S. Department of Agriculture, has been included in the millet test of the Ohio Station, its cultural

requirements being similar to that of millet. Botanically, it is a close relative of sorghum, the original form of both being the well known, though sometimes troublesome, Johnson grass (sorghum halepense). Unlike the Johnson grass, however, it is strictly an annual, without rootstock, and has no weedy propensities. The inflorescence or head is a panicle like that of broom corn. The seeds are somewhat larger than are those of the broom corn millet and are reddish-brown in color. It is a vigorous growing plant having rather coarse forage (coarser than German millet) and at the Ohio Station attains a height of 3 to 5 feet. (Fig. 13.)

Fig. 11. Barnyard millet. One-fourth natural size.

As may be noted from Table VI, in yield of air dry forage it compares very favorably with millet, it being surpassed in 1913 by the Barnyard and German and in 1912 by the Barnyard only. Little is known as yet regarding its feeding value, though Professor Piper reports that at Chillicothe, Texas, "horses ate it readily and perfectly clean."

CULTURE

Soil and fertilizers: Millet may be grown with varying degrees of success on most any kind of land; but on rich, mellow soils it does best.

Like sorghum, and for the same reason, millet bears the reputation of being "hard on the land." However, the exhausted effect usually passes away in a short time.

Well-rotted stable manure or readily soluble commercial fertilizers are best with which to enrich poor land for the growing of millet.

Seeding: In order to keep ahead of the weeds, millet should have all the advantages afforded by the preparation of an excellent seed bed—clean, firm, fine and moist.

Like sorghum, millet should not be seeded until all danger of frost is past and continued warm weather is assured. In favorable

seasons, seedings of the earlier varieties, such as the Hungarian, may be made, with chances of fair success, as late as the middle or latter part of July.

Millet may be broadcasted and harrowed in, or drilled with an ordinary grain drill, covering not to exceed 1 to 1½ inch deep.

When drilled solid as for hay, soiling or pasture, from 3 to 4 pecks per acre is none too much of the foxtail millets—the best for these purposes. If less than 3 pecks is sown the forage is apt to be coarse and unpalatable. If sown for either seed or silage, it is usually seeded in rows 24 to 30 inches apart—far enough to permit cultivation—using from 1½ to 2 pecks per acre—one-half that required for forage of fine quality.

When drilled solid, Barnyard millet is seeded a little lighter than the foxtail group, usually at the rate of about two pecks per acre.

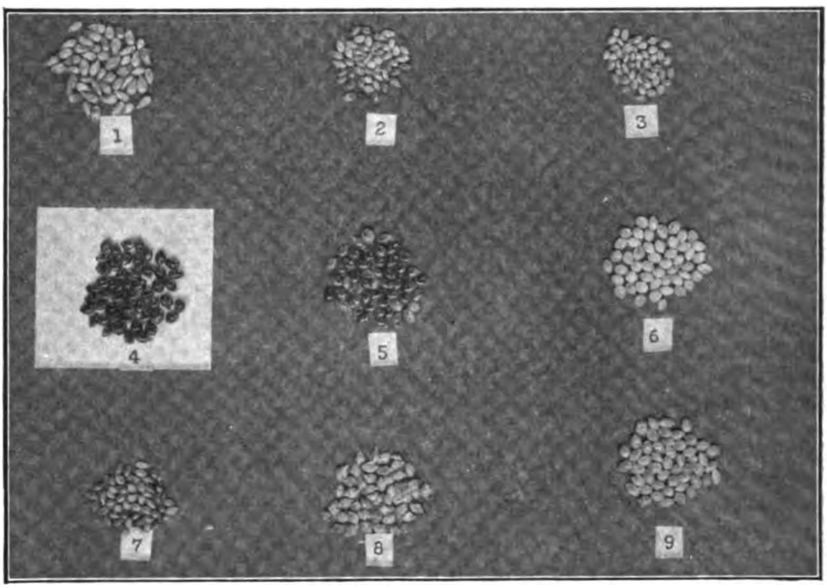

Fig. 12. Millet seeds. (1) Pearl, (2) Hungarian, (3) German, (4) Black Voronezh, (5) Early Fortune, (6) White French, (7) Red Siberian, (8) Barnyard, (9) Broom corn. Natural size.

HARVESTING

Hay: That some caution should be exercised in the feeding of millet hay has been shown by several experiment stations.[1] However, the danger is thought to be reduced to a minimum, if not quite eliminated, by cutting at what seems to be the most favorable time—when one-half or more of the plants are in head—and by feeding moderately and not too exclusively.

[1]N. D. Bul. No. 7. Mich. Bul. No. 117.

As millet approaches maturity it deteriorates as regards palatability and digestibility. Furthermore, the development of bristles may result in injury when fed to stock. It should never be allowed to stand until the seeds are ripe.

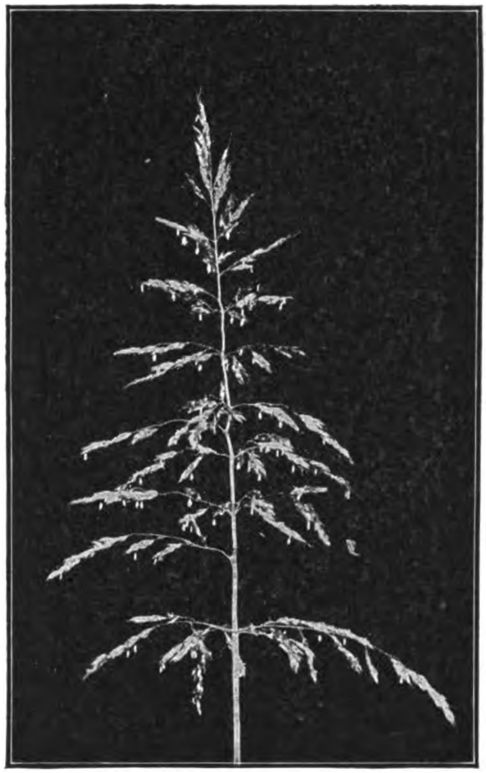

Fig. 13. Sudan grass.

The hay is cured practically the same as timothy. After lying for a time in the swath it should be piled in cocks, where, on account of its coarseness, it will usually need to remain a little longer than timothy.

When properly cut and cured, millet hay slightly exceeds timothy, both as regards composition and digestibility.

Soiling. For soiling, millet may be harvested any time after it is large enough to handle, usually 40 to 50 days after planting. For this purpose the foxtail millets are best, though some have obtained good results from the use of the Barnyard.

Silage: Like corn, millet is most suitable for silage when the seed is in the dough stage.

Seed: When grown for seed, millet may be cut and threshed with the same implements that are usually employed in harvesting wheat and oats. The separator, however, should be so adjusted as to give lighter wind blast, and the use of finer riddles, preferably clover screens, is recommended.

So little seed is produced in Ohio that average yields, having significance, are hard to establish. In a favorable season a reasonable expectation is from 15 to 40 bushels per acre, depending upon the fertility of the soil.

The straw does not make very good forage. The hard, woody stems contain little nutrition and the beards are liable to collect in

the stomachs of animals. However, if well cared for and properly supplemented with grain, it can be made to answer for more valuable roughage.

Other cereal forage grasses of more or less merit in the production of forage are rye, wheat and oats.

RYE

Pasture: Not being a sod-forming plant, rye is not well adapted to pasturing, but in the absence of permanent pasture, or in order to avoid too early pasturing of blue grass, it is useful, as it will furnish green feed earlier than any other cereal or annual forage crop. Under favorable conditions it will be ready to pasture by the latter part of April. Unless intended for hogs it should not be allowed to come in head, as with age it loses its palatability. It is at its best when not over one foot in height.

Concerning rye, Prof. B. E. Carmichael, Chief in Animal Husbandry at this Station, writes:

"Rye has a high value for use as very early spring pasture, especially for sheep, which are not so likely to injure the soil and waste the green feed as are hogs. The latter may do considerable damage in early spring by trampling and by rooting. Rye may often be used to good advantage in late fall or during the winter, providing the condition of the soil does not prevent. It may be pastured in the spring by cattle with good results, but not so early as by sheep. The practice of hogging down mature rye has been highly regarded by some. Excepting in rare instances, this practice has but little to commend it, as the rye is worth no more per pound than corn, if quite as much, and, of course, yields far less.

"The growing of rye or rape, or both, in corn that is to be harvested by hogs, or on oats stubble, is in high favor with some on account of the considerable amount of valuable green feed that will be produced if the late summer season is favorable."

Silage: If occasion demands, rye may be put in the silo, though as compared with corn silage it is neither as palatable nor as nutritious, For this purpose it should be cut when heads are nicely out or not later than when in bloom, using an ordinary grain binder. On account of air in stems it should be packed thoroughly and this is greatly facilitated by setting the silage cutter to cut the stems short—about one-half inch.

Hay: Though not very palatable, chemically, rye hay compares favorably with that made from the leading perennial grasses. If cut when nicely in head, it makes fairly desirable hay and is eaten with moderate relish.

Under average conditions from 2 to 4 tons per acre of dry forage may be expected.

Cover crop: In the Ohio Station's work with cover crops, embracing 20 tests including 14 different plants and combinations thereof, thus far (4 years) rye has proved to be the most reliable. From the standpoint of fertility maintenance it is, of course, less desirable than legumes, but in the latitude of Wooster rye is more sure to go through the winter than any of the other crops tested. If possible to seed the latter part of July or the first of August, as in corn at time of last cultivation, rye and hairy vetch may be seeded together, using 4 or 5 pecks of the former and 20 to 30 pounds of the latter per acre.

WHEAT

While wheat is harvested almost exclusively as grain, yet, like rye, the green forage may be utilized as pasture, soiling, silage and hay.

Rank wheat, which is to be harvested for grain, may be pastured sparingly with hogs and sheep, providing the ground is not wet enough to poach, but such pasturing usually results in a slight reduction of yield, though in cases of excessive growth of straw it may result in a small increase of grain. Just when to pasture is difficult to determine as the after season has an important bearing upon the final outcome.

OATS

Pasture: Among the best spring crops for the production of early pasture are oats. As soon as they are 4 to 6 inches high—large enough to make a good mouthful—stock may be turned in. If desired, seed for permanent pasture may be sown with them and if pastured neither too heavily nor when the ground is too wet, little injury will result to the new seeding.

A slightly more desirable, and hence more satisfactory early spring pasture for cows and horses, is a mixture of oats, barley and rye—one bushel of oats and 3 pecks each of barley and rye per acre.

Though feasible, oats are in little demand for either soiling or silage purposes.

Hay: As a hay crop oats have several things to commend them. Pound for pound the hay is almost equal to clover and is superior to timothy. Clover is more likely to succeed when seeded in oats to be cut for hay rather than grain. Furthermore, it is an excellent crop with which to thicken a thin or old meadow. As soon as the weather will permit the oats may be disk-drilled in the thin clover

or timothy, using about 8 pecks per acre. Though oats and timothy do not mature together, yet, if cut at the proper time, the mixture makes hay of fair quality.

With reference to the best time to cut oats, there is considerable difference of opinion, but as the result of careful weighing and analyses of green oats cut at different stages of development, the South Carolina Station[1] concludes: "If a nitrogenous forage is desired, cut in the early milk stage when the whole plant is quite palatable; if a forage high in carbohydrates is desired, cut at the beginning of the dough stage; because, after this time, although there will be a continued increase in starch in the seed, the other parts are decreasing rapidly in feed value."

The value of oat hay depends somewhat upon the variety used, as among different varieties there is considerable variation both as regards quantity and quality of straw produced. In the five-year average of 36 varieties tested at the Ohio Station there was a difference in yield of straw per acre of 1,783 pounds.

Among the more leafy varieties having good quality of straw and, therefore, among the more acceptable for hay, are such as the Watson, Wideawake, Welcome and others.

Oats and field peas: Oats are frequently grown with field peas and the hay made from this mixture compares favorable with clover, not only in digestible nutrients but, also, when well cured, in palatability.

Adaptation: The culture of field peas is quite common throughout northern Ohio, but in the southern part of the state, where the temperature is somewhat higher, they are not at their best, though if seeded early, a fair crop may be expected.

Seeding: Both oats and field peas thrive best in cool weather and hence should be seeded as early in the spring as possible. The drill should be set—weighted if necessary—to put the peas in at least to a depth of 4 inches. If planted much shallower the peas are apt to dry up before maturity. The oats may be broadcasted or drilled at the same time (not the same operation) or, if the weather is favorable, a few days later, but before the peas begin to come up. If broadcasted, the oats should be harrowed in.

Three bushels per acre of this mixture is regarded as a good seeding, the proportion of each being varied to suit requirements. At the Ohio Station 3 combinations have been used, the results of which for 4 years are tabulated in Table VII.

[1]Bul. 163, p. 16.

TABLE VII. Oats and field peas. Pounds dry forage per acre.

Mixture of seed per acre	Year				4-year average	Protein	
	1909	1910	1911	1912		Percent	Lbs. per acre
2 bus. field peas—1 bu. oats...	4,200	6,650	4,900	9,960	6,427	10.1	649.1
1½ bu. field peas—1½ bu. oats	4,800	7,350	4,800	9,040	6,497	9.5	617.2
1 bu. field peas—2 bus. oats...	4,240	7,400	4,800	10,340	6,695	9.0	602.5

From this table it may be noted that the highest yield of total forage came from the heaviest seeding of oats and that the yield decreases as the proportion of oats decreases. As might be expected, in yield of protein per acre the reverse is true. However, the difference in quantity of protein is not great enough to leave much margin after allowing for the greater cost of seed incident to the use of the larger quantities of peas.

Therefore it would seem that when total tonnage is the chief object, oats should predominate, and when the chief object is feed of high quality the peas should be in excess.

A common proportion is 1½ bushel per acre of each, and in view of the greater possibility of lodging from the heavier seeding of peas, it may be regarded as one of the most satisfactory.

Varieties: Several varieties of field peas are offered on the market, such as the White Canada, Scotch Beauty, Black-eyed Marrowfat, but the one in most common use is the White Canada. This variety matures well with any of the midseason varieties of oats.

ROOT CROPS

Root crops is a rather indefinite term applied to a group of plants, chiefly biennials, having similar uses and adaptations and usually characterized by an enlargement of the primary root and stem.

Though they carry a small percentage of dry matter, they are an excellent source of succulent food possessing high dietetic value

So far as climatic conditions are concerned, root crops may be grown successfully throughout Ohio, but their culture is restricted by the rather limited conditions under which they can be utilized with profit, either as stock food or as a soil renovator.

As more and better succulent food can be produced cheaper with corn than with root crops, the growing of the latter for stock food is confined largely to the smaller farmers, the size of whose herds is such as not to warrant the erection of a silo.

Also, poultrymen, and dairy men who are feeding to make milk records, find it profitable to grow a few root crops.

As a soil renovator, root crops are of value in localities having heavy, clay soils as in many parts of northeastern Ohio. The ready access of air and water made possible by the decay of the roots of such crops has a beneficial effect upon tenacious soils.

Though the growing of root crops is not a prominent line of activity in Ohio agriculture, for the benefit of those who find them profitable, information regarding the culture of those most important in the state follows:

MANGELS

Soil and fertilization: A deep, rich, well drained loam is most desirable, though satisfactory crops may, with proper fertilization, be grown on the less productive clays and sands.

A calcareous, rather than an acid soil, is preferable.

They call for practically the same fertilization as corn. Like the latter they can make good use of phosphated manure—8 to 10 tons per acre being a good application. One hundred pounds of muriate of potash can likely be used with profit on most Ohio soils, as the crop is a heavy consumer of potassium. On land deficient in nitrogen—a condition indicated by lack of dark green color in leaves —80 to 100 pounds per acre of nitrate of soda will likely pay well.

Seed bed: Since the germination of the seed and the early growth of the plants are very slow, a seed bed of good tilth and free from weeds is important else the young plants may be overwhelmed by the latter. The nature of the roots calls for rather deep plowing and, where the topography and texture of the soil permits, this work may well be done in the fall, the manure, if any, being plowed under.

Seeding: Mangels are usually seeded from May 1 to 20, in rows 28 to 36 inches apart, using 5 to 10 pounds of seed per acre. They should be covered not to exceed three-fourths inch deep.

They may be planted with a hand drill or, by closing a part of the hoes, a grain drill can be adapted to this work.

Cultivation: Before the rows become visible, cultivation should begin, using such implements as a light harrow or weeder. After the plants are large enough so that the rows may be followed easily, cultivation with the ordinary sorts of implements should be frequent and should continue for 6 to 10 weeks, or until the tops cover the ground.

At the time the plants have about four leaves the process of blocking and thinning begins. Blocking consists in removing with a hoe all the plants in the row except little bunches 6 to 10 inches apart, the distance depending upon the variety. Immediately

thereafter the bunches should be thinned by hand to one plant. The hand thinning is very important and at the same time it is the most expensive and most laborious work connected with the culture of mangels.

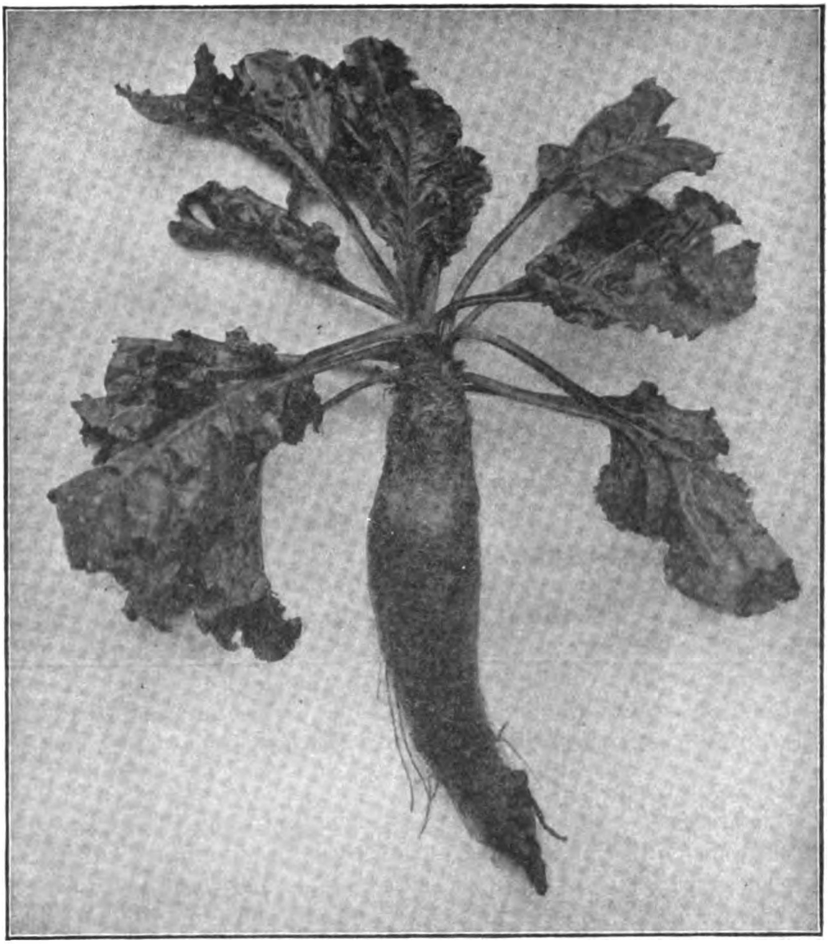

Fig. 14. Mangel (Long-red.) About one-sixth natural size.

Harvesting: Harvesting embraces three distinct operations—lifting, pulling and topping. Lifting consists simply in loosening the mangels—an act accomplished either by cutting a single furrow with a small plow on one side of the row or by the use of a double-pointed plow so constructed that a point passes on either side of the row.

The pulling and topping are usually done by hand, after which the mangels are thrown into piles.

Storing: In the absence of a root cellar, mangels may be "pitted" by throwing into ricks and covering with alternate layers of straw and earth, adding a layer of earth as the severity of the weather increases. In locating the pit an elevated site should be selected in order to provide good drainage.

Yield: The range in yield of mangels is large, varying from 15 to 40 tons. On the Station farm in 1911 they yielded at the rate of 21½ tons per acre.

Feeding: For most livestock mangels are cut into small pieces or sliced, though for poultry this is unnecessary. For a thousand-pound animal 25 to 50 pounds per day is regarded as a good feed; the amount depending upon the quantity of other feeds used.

Varieties: Mangels are usually classified with respect to shape, the chief forms being long, intermediate, tankard and globe. In color of flesh they may be white, pink, red, yellow, golden and purple or black. Varieties are often designated by coupling the names used to describe the mangels with respect to form and color, as Long Red, Golden Tankard, Yellow Globe, etc. (Fig. 14.)

In the long form the length of root (sometimes 20 or more inches) exceeds that of the breadth 3 to 4 times and one-half or more of the root may be below the surface of the ground, thus the successful culture of this type is restricted to deep soils. As may be inferred from the names, all the other forms of mangels have shorter roots and consequently are adapted to shallower soils, the globe type being especially suited to the lighter types of land.

The half-sugar mangel, said to be a cross between the sugar beet and mangel, is regarded as one of the best for stock food.

SUGAR BEETS

Sugar beets are mangels highly developed along the line of sugar production. Aside from composition they have come to differ from mangels with respect to size, shape, color, depth of growth and in keeping qualities. Sugar beets are smaller than mangels (fig. 15), usually conical (Vilmorin's Improved) or pear shaped (Klein Wanzlebener); rarely other than white in color; they grow entirely beneath the surface of the ground, consequently are difficult to harvest, and are less adapted than mangels for late storage in spring.

As the yield per acre is less and the cost of harvesting is greater than that of mangels, the latter are more satisfactory as a source of succulent feed.

On the Station farm in 1911 they yielded at the rate of 12½ tons per acre.

The culture of sugar beets is essentially the same as that of mangels. The former, however, are usually seeded thicker than the latter; the usual rate per acre for sugar beets being 15 to 20 pounds, and in rows 18 to 24 inches apart.

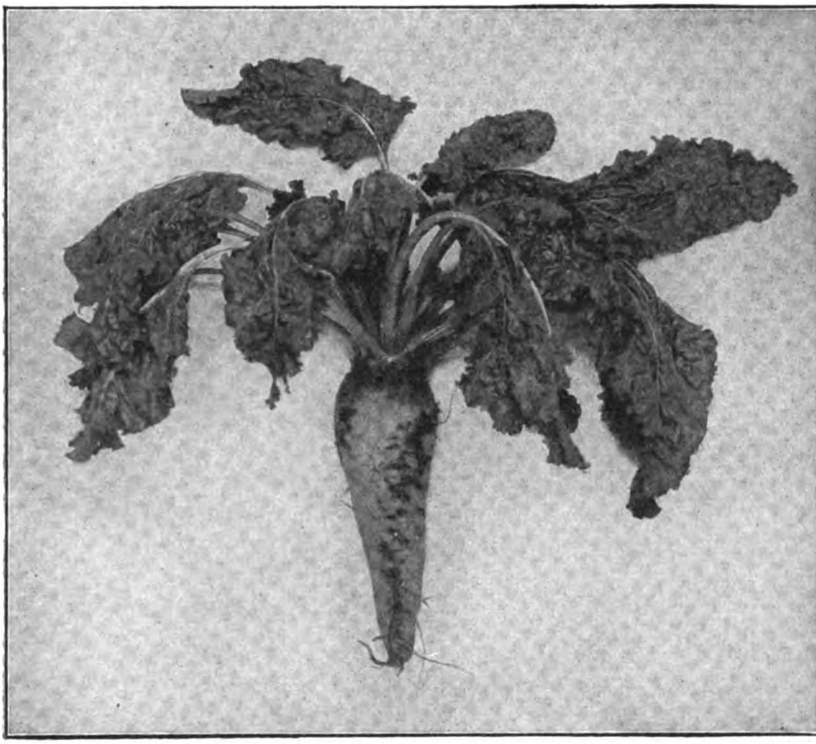

Fig. 15. Sugar beet.

For the production of sugar, the culture of beets is restricted to a comparatively cool climate; such as that which predominates throughout the region of the northern limit of the corn belt. In warmer climates they are not only more subject to disease but often the content of sugar is too low for profitable production.

TURNIPS

Adaptation: With respect to soil, turnips thrive best on silt loams; stiff clay and sandy soils not being well suited, the former on account of the difficulty with which a finely pulverized seed bed is prepared, the latter on account of incapacity to hold moisture. Like mangels, turnips thrive best on a calcareous soil. Not a great amount of sunshine is required, a cool, damp climate being favorable.

Culture: In preparation of seed bed, cultivation, harvesting and storing, practically the same operations employed in the culture of mangels apply in the growing of turnips. However, in the earlier stages of growth turnips grow more rapidly, hence less difficulty is experienced in keeping the seed bed clean while the plants are young.

They may be seeded successfully at any time from the first of May to August. With a hand garden-drill they may be seeded in rows 18 to 30 inches apart, using from 2 to 5, usually 3 pounds, of seed per acre. Seeded broadcast, a little more seed is required, the usual amount ranging from 4 to 6 pounds.

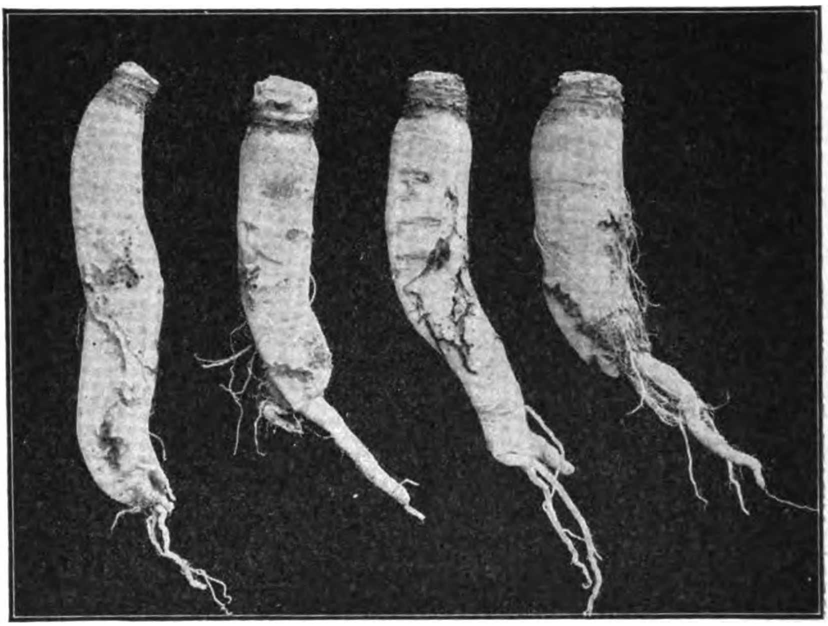

Fig. 16. Cowhorn turnips.

Turnips are often seeded in corn at the time of last cultivation, both for the purpose of furnishing fall feed and, on some types of land, especially heavy clays, for the effect on the texture of the soil. If the height of the corn interferes with the proper distribution of seed on foot, in the experience of the Ohio Station it has been found practicable to broadcast it on horseback, care being taken to cover the ears of the horse with small bags. The seed may be covered with a light cultivator. One-half to three-fourths inch is about the proper depth to cover turnip seed.

Yield: Turnips yield less than mangels, 10 to 25 tons per acre being regarded as fair yields.

Varieties: Turnips are usually classified with respect to either form or color of flesh.

With reference to form, a common grouping is long, tankard or spindle shaped, round or globe and flat, the name in each case indicating the shape. The form of the upper part is sometimes further described as "flat topped" or "round topped"; the latter being preferable as it is less subject to decay.

In the long varieties the length exceeds the breadth by three or more times. A common form of this type, and one of the most valuable as a catch crop, is the Cowhorn. (Fig. 16.)

With reference to color, turnips are frequently grouped as white-fleshed or yellow-fleshed. On the basis of the color of the upper or exposed part, they are further subdivided, the white-fleshed varieties as "white tops," "green tops," "purple or red tops" (Fig 17), and "gray stones," a mottled appearance produced by transverse streaks of green and purple; the yellow-fleshed varieties as "yellow tops," "green tops" and "purple tops."

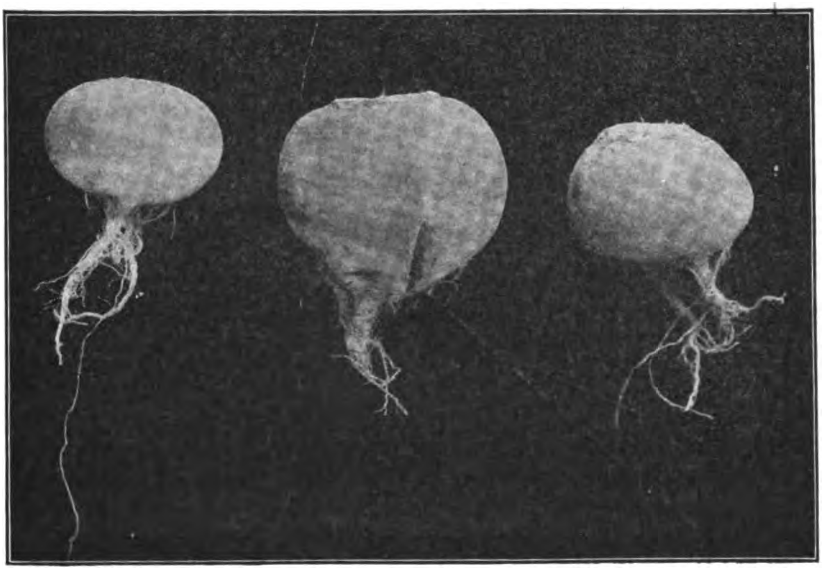

Fig. 18. Purple top turnips.

The white-fleshed varieties are characterized by rapidity of growth, soft flesh, low feeding value and little resistance to frost. They are best suited to fall and early winter feeding. This class of turnips is usually seeded broadcast, it being considered of too little value to sow in rows and cultivate.

As compared with the white-fleshed varieties, the yellow-fleshed grow less rapidly, are firmer, have higher feeding value, are more resistant to frost and may be kept sound for a much longer period of time.

RAPE

Classification and adaptation: Though not looked upon as a root crop, botanically rape is a close relative of mangels and turnips, all being members of a well known and populous group—the mustard family.

Fig. 18. Rape, drilled in rows; 59 days after seeding.

The soil and climatic adaptation of rape is similar to that of turnips. It is partial to rich loams and, like corn, it responds readily to liberal applications of stable manure and fertilizers.

It calls for the preparation of an excellent seed bed; one which is firm, fine and moist.

Seeding: The usual time of seeding is from April to July 15, though in some years the weather permits of successful seeding as early as the latter part of March. As a catch crop it may be seeded in corn at the time of last cultivation and in the same manner as turnips.

It may be sown solid (broadcasted or drilled) or in rows 24 to 28 inches apart. For seeding in rows a hand drill may be adjusted or a grain drill may be adapted by closing a part of the hoes. The

seed is best distributed from the grass-seeding attachment of a drill, piping the seed through the hoes, setting the drill to cover it completely though not deep. If broadcasted, 5 to 8 pounds of seed per acre are required; if drilled in rows, 2 to 3 pounds are sufficient.

Cultivation: Seeding in rows permits of cultivation which results in a more rapid growth and, during the pasturing season, less is wasted by trampling. (Fig. 18.)

Unlike mangels, rape grows rapidly from the first, and if given about three cultivations at intervals of one week, it should be ready to pasture in 6 to 10 weeks.

Regarding the value of rape as a forage plant, Prof. B. E. Carmichael writes:

"Rape has proved a very valuable source of green feed for both sheep and swine at the Ohio Station. Sheep and lambs will do well on rape with no grain. Young hogs, or, indeed, hogs of any age that are expected to yield rapid gains, should be provided with a fairly liberal grain ration in connection with rape pasture. On account of the large proportion of crude protein in rape, there is much less need for nitrogenous supplements in connection with corn and rape than with corn in dry lot. Bulletin 242 gives the results of a number of experiments in which use was made of rape for swine."

If not pastured too closely, rape will continue to furnish green forage throughout the season, the amount varying with the fertility of the soil.

Varieties: While there are numerous types of rape, including many hybrids and crosses, yet all may be grouped in two classes: annual or summer, and biennial or winter rape.

From the seed, an oil is extracted which is used for lubricating and lighting and the refuse or "rape cake" is highly prized as stock food and fertilizer.

The biennial or winter rape, of which the Dwarf Essex is a leading variety, is the kind commonly grown in this country for forage. This type produces seed only in localities where it can withstand the winter. Most of the seed used in this country is imported from Europe.

EXPERIMENTS IN WINTER LAMB PRODUCTION

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., FEBRUARY, 1914

BULLETIN 270

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

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EXPERIMENTS IN WINTER LAMB PRODUCTION

PART I: RATIONS FOR EWES AND LAMBS
PART II: COST OF PRODUCTION

By J. W. HAMMOND

INTRODUCTION

The hothouse lamb is a special product for which the demand at high prices is rather limited, yet the production of such lambs is an industry which has proved profitable on a number of Ohio farms. Many sections of Ohio not only have access to transportation facilities necessary to deliver the lambs to market in good condition, but also possess the sheep from which to raise the lambs, and the feeds to produce lambs of prime quality. The fact that the prices paid for hothouse lambs in the eastern cities the last year or two have been lower than those paid in some preceding years emphasizes the importance of keeping in mind the possibility of an over-production of this commodity. However, young lambs during the winter are a delicacy for which there doubtless always will be a good demand in western as well as in eastern cities, and the production of such lambs offers possibilities even though prices should not be maintained at the level of former years.

The term "hothouse lamb" frequently leads to the very erroneous impression that such a lamb is a delicate creature, requiring special care and artificially heated buildings. On the contrary, the hothouse lamb is very robust. Artificially heated, or even especially warm, buildings are not at all necessary. The term "hothouse" has probably been applied to such lambs because they are produced at a season when lambs are not ordinarily produced, and in this respect are comparable to the artificial or out-of-season products of hothouses or green-houses.

1. Digestion of foods.
2. The balance of mineral acids to bases.
3. Effects of magnesium on calcium metabolism.
4. The significance of creatinin excretion.
5. Mineral requirements and paths of elimination.

PLAN OF EXPERIMENT

Five cross-bred Yorkshire-Chester White barrows, 6 months old and all from the same litter, were the subjects of this experiment. Confined in metabolism crates they were taken through eight 10-day collection periods, separated by 7-day intervals on the next ration to follow, the change of food being made abruptly at the end of each collection period. The five animals were given the same food, our results, therefore, being based on five repeats.

The foods used in the several periods were as follows:

1. Corn.
2. Corn; soybeans.
3. Corn; linseed oil meal.
4. Corn; wheat middlings.
5. Corn; meat meal (digester tankage).
6. Corn; skim milk.
7. Corn.
8. Rice polish; wheat bran.

They were, therefore, the common practical foods for swine in this country, except ration No. 8, composed of rice polish and wheat bran, these feeds being selected on account of their very high content of magnesium in proportion to calcium. Corn was fed alone in the first and seventh periods to show any such changes as might be due to the long continued routine or to increasing age.

The observations covered the usual proximate analysis of foodstuffs and feces, daily nitrogen, creatinin and ammonia estimations on the urine, also determinations of the sodium, potassium, calcium, magnesium, sulphur, phosphorus and chlorine on foods, urines and feces, and further, a slaughter test on the five animals after the termination of the experiment.

METHODS OF EXPERIMENTATION

The metabolism crate used combines features from Gies's dog crate, Grindley's sheep crate, and McCollum's pig crate with ideas of our own, and was found to be entirely satisfactory for the purpose. Four of the crates are shown in Plate I, p. 227. The objects which we sought to attain in designing this crate were freedom of movement of the animal, free circulation of air, and the accurate collection, without admixture or contamination, of the excreta.

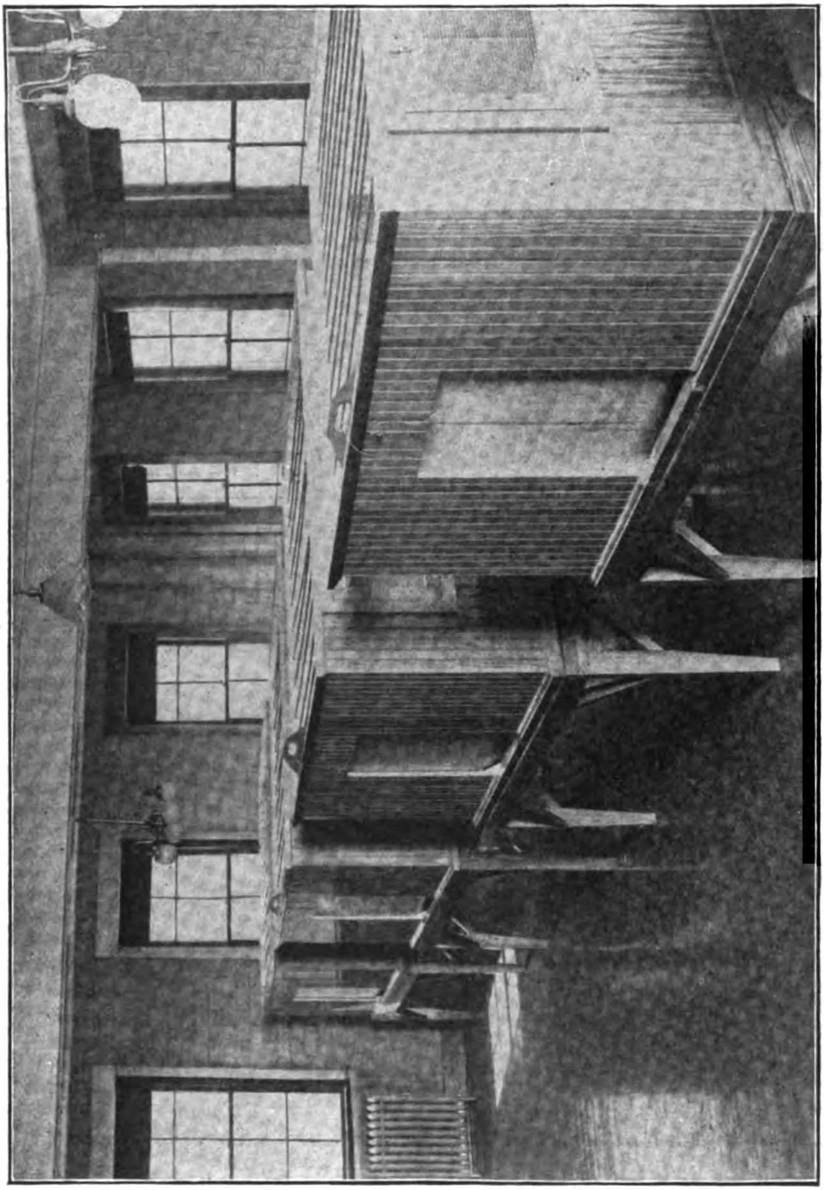

PLATE I Metabolism crates—Five such were used.

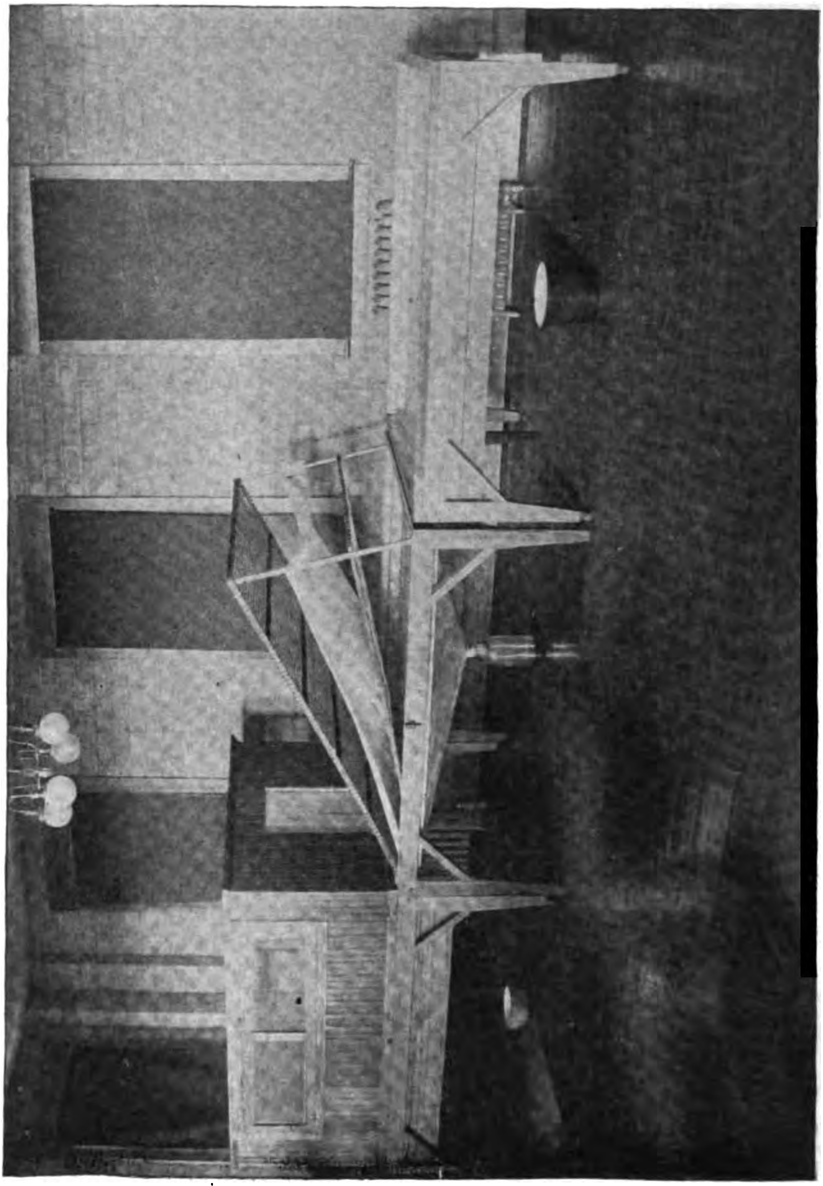

PLATE II Metabolism crate—Top removed, screens and cloth elevated.

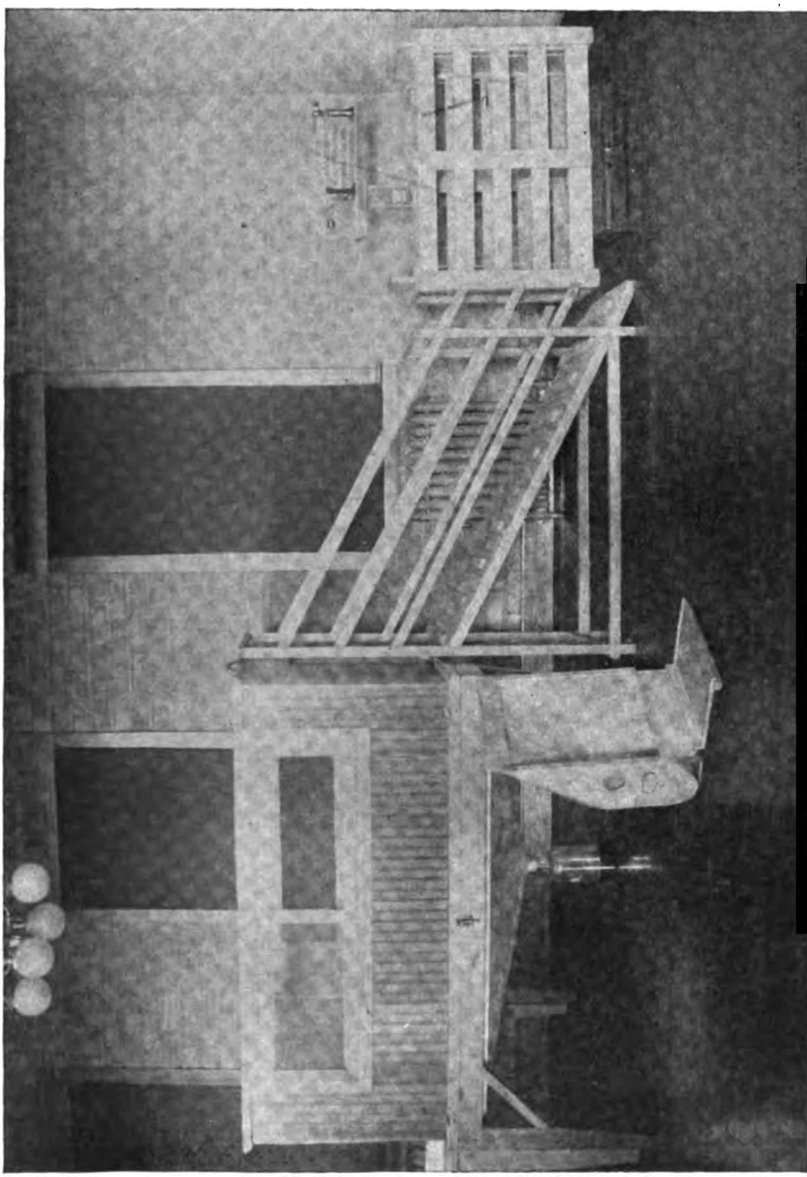

PLATE III Metabolism crate, feed box, equipment for weighing.

In Plate II, p. 228, the removable crate, which runs on rollers, has been shoved over onto the cleaning table, the pig walking along with the crate, and the screens have been elevated to show their relation to one another. When in place, the light screen below rests four inches beneath the heavy upper one on which the pig stands. It is used simply to support a fine cloth which retains the feces but allows the urine to pass through into the hopper, and then through a plug of cotton into a bottle under the crate. The cotton and bottle are both treated with thymol. The drain table at the right is used in scrubbing the heavy screen. The two cleaning tables mentioned are covered with galvanized iron, and are built to drain to an outlet. They are on casters and are pushed from crate to crate for the daily cleaning and collection program.

Plate III, p. 229, shows the chute, weighing crate and scales used in weighing the pigs, and also a feed box. The food was placed in the boxes in another room, and the boxes were then attached to the crates with a single hook, each, after raising the sliding doors shown in Plate I. After the food was comsumed water was given in the same trough by pouring it in through the hole shown in the end of the feed box. This hole is closed with a slide door. Small amounts of food sometimes falling upon the little platform attached to the feed box were returned to the trough, and were consumed with the next feed.

The pigs were fed twice daily. The foods given during each period were all weighed at the beginning of the period, and samples for moisture and fat determination were taken at this time, complete analyses having been made before the beginning of the experiment.

Repeated attempts were made to apportion the food in accord with the creatinin elimination, and the water in accord with the amount of food, but we found it impracticable to adhere in all periods to the first principle, and the second was abandoned entirely, the desire of the animal for water standing in no definite relation to the food consumed. Water, therefore, was generally given *ad libitum*, but measured.

The pigs were scrubbed daily with distilled water to which was added a little phenol, but no account was taken of cutaneous elimination in the experimental work. During intermediate periods the pigs were scrubbed with soap.

Unless the pigs were washed frequently they became sticky and uncomfortable. Then they rubbed off hair which fell into the feces, and had to be picked out in the preparation of the samples for analysis.

One would naturally suppose that the comfort of so dirty an animal as a hog would require no washing, but as a matter of fact a

pig does not prefer to be dirty. Because of his heavy overcoat of fat he wants first to be cool. To be cool, he must be wet. His only way to get wet, ordinarily, is to wallow in mudholes. Incidentally, he also frees his skin from its secretions, and thus completes his comfort.

By the use of wire brushes the feces were removed daily from the upper screen and from the cloth, and were placed in friction-top cans in a cooling room at about 0° F. The urine cloth was washed daily in boiling distilled water, as also were the lower screen and urine hopper. These washings were added to the urine sample. The heavy screen was scrubbed at the end of each 10-day period, and this wash water was also added to the urine sample.

The urine was collected morning and evening, and kept in a cooling-room at 32° F. Each morning the urines from the day before were measured, and aliquots taken out for preservation and for the daily determinations. The determination of the inorganic elements in the urines of the first period was omitted because of errors due to the precipitation of phosphates in the urine bottles. This difficulty was obviated in subsequent periods by the use of 10 c. c. of acetic acid in the day's urine on placing it in the cooler. The feces were marked by the feeding of carmine, and were sampled at the end of the period by grinding in a frozen condition, in a power sausage mill.

Chemical analyses were made in triplicate by methods as follows:

Moisture: Vacuum method, over sulphuric acid.

Nitrogen: Kjeldahl method; on foods and feces by the Gunning-Arnold-Dyer modification; on urine, according to Hawk.

Fat: Ether extract.

Ash: On foods by the hydrochloric acid leaching method; on feces by the water leaching method.

Crude fiber: Original; see Ohio Bul. 255.

Carbohydrates: By difference.

Metabolic nitrogen: Pepsin digestion method.

Urinary ammonia: Folin method, as modified by Steel.

Creatinin: Folin method.

Sodium: Original; see Ohio Bul. 255.

Potassium: Lindo-Gladding method.

Calcium: McCrudden's method.

Magnesium: McCrudden's method.

Sulphur: Peroxide and carbonate methods.

Chlorine: Provisional method of the A. O. A. C.

Phosphorus: Official gravimetric method after nitric-sulphuric acid digestion.

NOTES ON METABOLIC NITROGEN DETERMINATION

The nitrogen of the feces is found in (1) food residues, (2) bacteria, and products of their metabolism, (3) epithelium from the digestive tract and (4) residues from bile and digestive juices.

From this heterogeneous group of substances we desire to separate those portions which represent digestible food constituents. This fraction is of interest especially as giving us a basis for the determination of the amount of nitrogen in the feces which represents *indigestible* food constituents. The digestibility of the food nitrogen is determined by dividing its amount into the same, *minus* that of the indigestible feces nitrogen.

At best, from the nature of the case, this estimation embraces a considerable element of conventionality. Certainly no known method gives a scientifically accurate result; still there is considered to be ample warrant for the determination, in its practical usefulness.

The largest sources of error in the determination of metabolic nitrogen by the usual pepsin-hydrochloric acid method are as follows: (1) The indigestible food nitrogen may have become partially soluble in pepsin-hydrochloric acid during its passage through the alimentary tract. This factor would tend to exaggerate the metabolic nitrogen and thus to lead to overstatement of the digestibility of the food nitrogen. (2) The digestibility of bacteria and their metabolic products contributes to the determination an element of error the nature and degree of which have not been determined.

As to the practical accuracy of the method, we find one bit of evidence in our results. The nitrogen of skim milk, which presumably is practically all digestible, appears, from our results with the pepsin-hydrochloric acid method, to be digestible to the extent of 99.12 percent. The net error of the method, therefore, would seem not to be large.

BEHAVIOR OF THE ANIMALS

The progress of the experiment was marked by no unfavorable incidents of moment. The pigs remained in good health, and did not appear to suffer from the confinement. In hot weather they were kept comfortable with electric fans. The gain in weight was very satisfactory for pigs so fed, and it seems to us unlikely that such an investigation could well be carried out under more favorable circumstances than attended this series of experiments.

DIGESTION OF FOODS

The literature of animal husbandry is strikingly poor in data on the digestibility of foodstuffs by swine, and the experimental work upon which rest the very few figures available is exceedingly scanty.

The digestion coefficients which we are reporting (Table IX, p. 248) are based on five repeats, the detailed data being given in previous tables.

The digestibility of corn in the first and seventh periods is very nearly the same, the only notable difference being that the crude fiber of the corn in the seventh period seemed to be less digestible than in the first. In consideration of the small amount of crude fiber in corn this difference in digestibility in the two periods is of no importance.

The digestibility of the protein of the cereal and leguminous seed products is remarkably constant, the averages of results from the five individuals varying but two percent. The protein of meat meal, however, is several percent less digestible, and the protein of milk is several percent more digestible than the protein of the foods of vegetable origin. The low digestibility of the protein of the meat meal is perhaps due to the presence of hair and other refractory nitrogenous substances, or to the high degree of heat to which it is subjected.

The admixture of soybeans, meat meal or skim milk with corn so increases the digestibility of the starch of the corn that the apparent digestibility of the carbohydrates of the supplementary foods becomes over 100 percent.

In the same way meat meal and skim milk, when fed with corn cause such a decrease in feces ether extract as to make the digestibility of the fat of these foods apparently much more than perfect, the percentage of digestibility of the fat of skim milk seeming to be about 162 percent, and of the meat meal 139 percent, which facts suggest the prominence of bile residues in feces ether extract, and also the fact that the determination of digestibility of ether extract is, to borrow an expression from Thudichum, "a ceremonious delusion."

A still more anomalous condition exists with reference to the effect of meat meal and skim milk on the digestibility of the crude fiber of corn. These supplements so decrease the digestibility of the crude fiber of the corn with which they are fed that the crude fiber of meat meal which is present to the extent of 4 or 5 percent, because of the inclusion of a certain amount of paunch contents, seems to be digestible to the extent of 101 percent less than nothing, while the skim milk when fed with corn becomes chargeable with an extensive minus digestibility of crude fiber, of which, of course, it contains none at all. These effects of the supplementary feeds on the digestibility of the crude fiber of corn may be considered as an expression of their influence on the bacterial flora of the alimentary tract.

Digestion coefficients of less than nothing, and of more than 100 percent, show that the determination of digestibility of supplementary foods by difference, in the usual way, is not free from objection, since the supplement affects the digestibility of the basal ration, which the method assumes to be constant. It seems to us more nearly correct, however, to use the figures obtained than to call all minus coefficients zero, and to give a value of 100 percent to all those which seem to be above that figure.

In general our digestion coefficients are decidedly higher than the collected figures for some of the same foods as quoted by Henry in his "Feeds and Feeding."

Consideration of the magnitude of possible analytical errors and their bearing on the above results leads us to the conclusion that the anomalous character of the digestion coefficient for the nitrogen-free extract of soybeans is possibly, though not probably, due to experimental error. We are not able to account for any of the other coefficients of more than 100 or less than zero in this way. They apply, however, to constituents which are present in small amounts, and hence are not of great practical significance.

THE BALANCE OF MINERAL ACIDS TO BASES

Each of the rations contained an excess of acid to basic mineral elements. (See Table X, p. 249.) The magnitude of this acid-excess proves the pig to possess an extensive acid-neutralizing capacity.

The urinary ammonia excretion was found to vary directly with the excess acid of the ration (See Table X) provided that the protein of the ration remained about the same in amount, but any considerable increase in the latter also increased the urinary ammonia.

From the figures in Tables X, XI and XXI we do not see evidence of a close relation between calcium retention and either the excess of acid over basic mineral elements in the ration, or the urinary ammonia. This factor, therefore, seems not to be important in this connection in practical rations for swine, though of this fact we can not be certain, since we are unable to differentiate between the effects of calcium deficiency and acid excess.

With a constant calcium content such variations in mineral acidity as were present in these rations would doubtless affect calcium retention, but the variations in calcium intake in these cases were of so much greater magnitude than the variations in mineral acidity that the effects of the latter on calcium retention were not discernible.

The retention of calcium, however, (Table XII, p. 251) appears to be closely related both to the intake of calcium and to the ratio of calcium to magnesium in the food, stated in chemically equivalent

units; but our evidence does not make it possible to judge with certainty of the relative influence of these two factors. The greater loss of calcium in Period VIII than in Periods II and VII, however, in spite of greater intake, is probably due to the much greater proportion of magnesium to calcium in the food. The excess of magnesium to calcium in Indian corn is probably not an important factor, since neither one was present in sufficient amount to maintain equilibrium in these growing pigs.

CREATININ EXCRETION IN SWINE

Creatinin excretion (See Tables X and XIII, pp. 249 and 251) was shown to be a definite function of the individual animal, to increase with the growth of the animal, and to be entirely independent of the amount or kind of food.

A slaughter test at the end of the experiment (See Table XIII) showed that the five individuals compared with one another as to creatinin excretion in exactly the same order as with regard to the weight of each of the following: the live animal, the dressed carcass, the total flesh, the blood, and the bones. In regard to the internal organs, brain, lungs, liver, kidneys, and spleen, we failed to note such a regular correspondence with creatinin excretion.

During the first and seventh periods the pigs were fed on corn alone, the amount fed in the seventh period being slightly less than the amount fed in the first. In the seventh period, however, the pigs weighed 2½ times as much as in the first, and they excreted 2½ times as much creatinin. The relative creatinin excretion of the five pigs remained practically the same during five months.

These observations are in harmony with the conclusion of Folin that the creatinin of the urine is a product of endogenous nitrogen metabolism.

MINERAL REQUIREMENTS AND PATHS OF ELIMINATION

The extensive series of mineral balances in Tables XIV-XX show that in such a variety of practical rations it is impossible to reckon mineral requirements in a definite way, the reason being that the amount of a given mineral element necessary to maintain equilibrium is much affected by the other constituents of the ration. An amount which is quite sufficient for maintenance, or which even provides for marked retention, may be quite insufficient for maintenance under other dietary conditions. We shall, then, place emphasis more especially on the foodstuffs, as such, in relation to mineral balances, than upon the amount of their mineral constituents.

Table XXI sets forth the average daily rations and mineral balances for the five pigs together for each period; Table XXII shows the relative outgo of the several mineral elements in urine and feces as affected by the foods used in the different periods; and Table XXIII is a similar presentation, but with the retention, or loss, included; that is, urine, feces and retention (or loss) are all expressed in percentages of the intake.

Salt was fed in all periods at a uniform rate of one part, by weight, to 256 parts of other food, except that the skim milk fed in Period VI was not considered in this connection. This allowance of salt seems to be more than sufficient to maintain equilibrium.

The balance of intake to outgo of sodium was much affected by the water drunk. Those individuals which drank the least water in proportion to sodium intake retained the most sodium. Those which drank the most water retained the least sodium, and eliminated the largest proportion of the sodium intake in the urine. We are not able to explain the slight negative balances of sodium in Periods V and VII (see pp. 255 and 257), but incline to ascribe them to influence of temperature, respiration, perspiration and water drinking, and therefore to consider them as not particularly significant.

A large sodium intake (see Table XXI, p. 259) increases the feces sodium as well as the urine sodium, but not to nearly so great an extent. Much less than half of the sodium outgo is usually contained in the feces; but in one period, during the feeding of the ration of wheat bran and rice polish, the feces contained 46 percent of the outgoing sodium, accompanied by a very small amount of chlorine. The peculiarities of the mineral metabolism on this ration were enormous urinary potassium (an average of 15 grams per day) unaccompanied by equivalent amounts of mineral acid, and a like excessive amount (14.9 gm.) of feces phosphorus accompanied by magnesium and other bases in abundance.

As with sodium, so with chlorine, the pigs which drank little water retained much of the element. The chlorine balances were almost all positive, but did not vary at all closely with the sodium. The only negative chlorine balances were on the meat meal ration during the maximum chlorine intake of the whole series. The feces usually contain less than one percent of the outgoing chlorine.

In the light of these results it is suggested that the salt retention of fever may be, in part, due to the relation of water to salt-balance. With elevated temperature and increased respiration the water intake may be insufficient to meet the increased outgo.

The potassium balances were all positive except during the period of greatest intake, on a ration of wheat bran and rice polish; here they were all negative. With the minimum intake of 5.9 gm. of potassium on corn alone there was a retention of 1-1.5 gm. of this element, but with an intake of 17.5 gm. on rice polish and wheat bran, there was loss. On this intake of 17.5 gm. per day there was an outgo of 15 gm. through the urine, as we have said before, unaccompanied by corresponding amounts of mineral acid, the urine thus possessing the general character of that of the herbivora. This negative balance of potassium may be considered as due to an over-response of the organism in its protective elimination of the excessive amount of potassium absorbed. Probably the entire loss of potassium represents storage in excess of the requirement during previous periods on other rations. The urinary excretion shows that the loss is not due either to a failure of the animal to digest and absorb potassium or to a reexcretion into the intestine, and the large retention of phosphorus coincident with a loss of calcium would favor potassium retention.

Urinary excretion of potassium is low if the retention is high, and is high if the retention is low. The proportion of potassium to sodium in the intake did not determine the proportion of urine to feces sodium, nor the outgo of sodium.

All of the sulphur balances in these experiments were positive. The greatest sulphur retention occurred during the periods of greatest calcium retention, and the lowest sulphur retention likewise was during low calcium retention. So close a correspondence of nitrogen and sulphur retention was not observable. The urinary sulphur is usually much greater than the feces sulphur, but may be less in individual cases. This proportion is much affected by the kind of food, but also, in prominent ways by individuality.

On the rations containing meat meal and milk, and on these only, calcium storage was liberal. In this connection we would mention the considerable bone content of the meat meal. Grain foods were shown to be more deficient in calcium than in any other of the mineral elements studied. This means that under ordinary farm conditions the use of forage crops is necessary to furnish the calcium in which the grains are deficient. On a cereal diet calcium starvation is the rule.

The negative calcium balance on corn alone was to be expected, but the negative balance on corn and soy beans was a surprise. With each pig on this ration the feces alone contained more calcium than the food. It is not known if this fact is at all related to the high fat-content of the soy beans, or to indigestibility of their calcium

compounds; but soy beans are not rich in calcium; at best they could not possibly sustain liberal calcium retention. The high calcium content of leguminous plants as a whole is much more characteristic of their leaves and stems than of their seeds.

It is not apparent that in any case an abundance of feces phosphorus is responsible for negative calcium balances.

The magnesium balance was not at all closely in accord with the intake. On about 2.25 gm. intake with soy beans there was retention; with about 9.25 gm. intake on wheat bran and rice polish there was loss. The magnesium loss was through the feces. This high fecal outgo of magnesium seems to have been due in part to the enormous phosphorus intake, but apparently not to this factor alone.

The magnesium of the food is shown to be a prominent factor in the partition of the phosphorus between urine and feces, an increased proportion of magnesium to phosphorus in the food increasing the proportion of feces phosphorus to urine phosphorus. There was no such prominent effect of magnesium to restrict phosphorus retention.

Magnesium balances were negative on the rations containing linseed oil meal, meat meal, rice polish and wheat bran, and also on the ration of corn alone. Magnesium was retained only from rations containing soy beans, wheat middlings and skim milk. That magnesium should be so commonly deficient in these practical rations is surprising.

The phosphorus balances in these experiments were all positive except for one individual on the ration of corn alone. In no case, however, was there any considerable retention of phosphorus on this ration. Except in one case the phosphorus retention in the several periods was in the same order as the intake. This exception was the ration containing wheat middlings. The peculiarity of the phosphorus of this ration was a large proportion of triticonucleic acid, and the phosphorus of this ration was much less efficiently retained than the phosphorus of the rations containing meat meal and milk. With a much smaller intake of phosphorus in meat meal and milk the retention was much greater. Two circumstances unfavorable to phosphorus retention in the wheat middlings ration were the presence of much less calcium and much more magnesium than in the meat meal and milk rations. The results were increase in both urine and feces phosphorus.

During the feeding of skim milk there were lower proportions of potassium, magnesium, sulphur, chlorine and phosphorus in the feces than during any other period; and this period was also characterized by the maximum percentage retention of the calcium, magnesium, sulphur and phosphorus intake.

Corn is shown to be more deficient in calcium than in any other nutrient; its magnesium content is also low, and its phosphorus content allows of but slight retention. At the same time the nitrogen retention is quite considerable. It is true that the pigs were not on what would ordinarily be considered as full feed, but we do not believe that this fact decreases the significance of our results, since the amount of corn consumed was sufficient to provide for considerable nitrogen storage. In spite of the slight retention of phosphorus we consider its amount insufficient, since we have here hardly more than the requirement for maintenance, at a time of life which would naturally be characterized by extensive storage of phosphorus.

The results, in general, show that the mineral requirements of swine are apt not to be satisfied during cereal feeding. A dry-lot fattening process probably involves, as a rule, considerable draft upon mineral stores previously accumulated during periods of access to green feeds.

Other ideas than those in this article, have been expressed, regarding the nutritive deficiencies of corn. Thus T. B. Osborne (Science, Jan. 31, 1913) writes:

"The results here presented leave no doubt that the deficiency observed in the practical feeding of corn meal is explained largely, if not wholly, by the unique chemical constitution of zein which forms such a large part of its proteins."

Our results show that, whatever the protein deficiencies of corn, its mineral deficiencies are more pronounced, since, in balance experiments, the deficiencies in calcium and other minerals are immediately made manifest by negative balances or deficient storage, while the protein deficiencies, whatever their nature, allow liberal nitrogen retention.

A considerable degree of independence exists between nitrogen and mineral metabolism, such that, for limited periods, mineral retention may occur coincident with nitrogen loss, but a complete final dependence of mineral retention on nitrogen metabolism is suggested by the work of Gregersen (Zeitschr. physiol. Chem. 71 (1911), 49-99) who found, in experiments with rats that, no matter how great the need for phosphorus, there was no phosphorus retention even from an overabundant intake, if this was furnished with a *nitrogen-free* ration.

In the light of this work it is not difficult to understand that, whatever the fundamental protein deficiency of corn, when an animal has been confined to a corn diet until the disturbance to nitrogen metabolism has become acute, we need not look for marked improvement from the giving of mineral nutrients, especially in an inorganic form.

From a practical point of view only those nutritive deficiencies of corn are of importance which are still manifest in the mixed rations in which corn is used. Successful farmers long since ceased feeding corn by itself to any animal, except under such conditions as allow the animal to pick up for himself in other foods those nutrients in which corn is deficient.

We all know that for practical feeding purposes the protein of corn is deficient in amount. We have also been shown that zein, the principal, but by no means the only protein in corn is, *by itself* an incomplete food, in the sense of being unable to sustain growth in rats, but we have no evidence that corn possesses protein deficiencies which remain manifest in the practical mixed rations in which we use corn.

These balance experiments show that the mineral deficiencies of corn are also to a large extent characteristic of the practical mixed grain rations in which many successful farmers use corn for hogs. It is true that in these experiments our periods were short, though they were longer than in most such investigations. The five repeats, however, are thought to go a long way toward protecting us from fair criticism on the ground of insufficiency of evidence. In considering the desirability of longer collection periods and more data it may be enlightening to some of our readers to learn that this experiment represents a full year's work for four men.

SUMMARY

Five pigs from the same litter, were used in a metabolism experiment involving eight 10-day collection periods, separated by 7-day intervals.

The foods used were corn alone in Periods I and VII; corn supplemented by soy beans, linseed oil meal, wheat middlings, meat meal (digester tankage) and skim milk in Periods II to VI, and a ration of rice polish and wheat bran in Period VIII.

The most important result of this investigation is the demonstration of the unsatisfactory character of corn, wheat middlings, linseed oil meal, soy beans, wheat bran and rice polish as sources of calcium for growing swine. Rations composed of these foods will not maintain normal growth of bone. The bony framework determines the size of the animal, and has much to do with determining its strength.

These pigs stored *9 to 10 times as much* calcium from rations containing milk and meat meal as from *the best one* of the rations of grain alone. These results emphasize the importance not so much of milk and of tankage as of *pasture*, *forage crops* and *dry roughage*, especially of leguminous plants, for these are our cheapest sources of those nutrients which the grain foods are shown to lack.

The important deficiencies of corn are considered to be calcium, phosphorus and nitrogen.

Phosphorus balances were positive, that is, phosphorus was stored on all rations, but phosphorus was insufficient for maximum growth in the ration of corn alone.

In the ration of rice polish and wheat bran, which contained 12 times as much magnesium as calcium, the excess of magnesium appeared to cause a loss of calcium from the animal. In the usual practical rations, however, this effect is not apparent.

These practical rations all contained an excess of acid over basic mineral elements. This excess acidity, however, did not appear to affect calcium retention, though we are not able certainly to distinguish between the effects of acid excess and calcium deficiency.

The ammonia of the urine was found to increase with the excess mineral acidity and the total protein of the ration.

One part of salt to 256 parts of other food seems to be more than sufficient for growing swine.

The balances of sodium and chlorine were largely controlled by the amount of water drunk.

There is an extensive metabolism of sodium apart from chlorine. The feces may contain an abundance of sodium but are nearly free from chlorine.

Magnesium tends to deflect the phosphorus excretion from urine to feces, and excessive phosphorus content of the ration limits the absorption of magnesium. With an intake of 2.17 gm. magnesium and 5.40 gm. phosphorus there was storage of magnesium; with an intake of 9.28 gm. magnesium and 20.71 gm. phosphorus there was loss of magnesium, combined with phosphorus, through the feces.

The potassium of these rations was more than enough in all cases. With the maximum intake, however, on the ration of wheat bran and rice polish, there was a loss of potassium, apparently through an excretion of previously stored excess.

The urinary potassium varies inversely as the retention.

Nitrogen and sulphur balances were all positive.

Sodium, potassium, sulphur and chlorine were excreted in larger proportion in the urine than in the feces, while calcium, magnesium and phosphorus left the body more largely in the feces.

The digestibility of the starch of corn is increased by the feeding with it of soy beans, tankage and milk. Tankage and milk also increase the digestibility of the fat, and decrease the digestibility of the crude fiber of corn.

Creatinin excretion in the urine was shown to be entirely independent of the food, and to vary among the several individuals in the same order as live weight, and weight of dressed carcass, flesh, bones and blood.

TABLE I. Composition of Foods—Percent Fresh Basis.

Foods	Moisture	Protein (Nx6.25)	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
Corn (Period I)	10.425	9.074	72.349	4.048	2.841	1.263	0.355	0.027	0.013	0.113	0.153	0.065	0.271
" (" II)	10.565	9.060	72.236	4.042	2.837	1.261	0.354	0.027	0.013	0.113	0.153	0.065	0.271
" (" III)	10.500	9.066	72.288	4.045	2.839	1.262	0.354	0.027	0.013	0.113	0.153	0.065	0.271
" (" IV)	11.110	9.005	71.796	4.017	2.820	1.253	0.352	0.027	0.013	0.112	0.152	0.065	0.269
" (" V)	11.315	8.984	71.629	4.008	2.813	1.250	0.351	0.027	0.013	0.112	0.152	0.065	0.269
" (" VI)	"	"	"	"	"	"	"	"	"	"	"	"	"
" (" VII)	"	"	"	"	"	"	"	"	"	"	"	"	"
Soy beans	7.385	40.706	21.961	18.465	4.995	5.155	1.962	0.5692	0.20764	0.2358	0.4206	0.0331	0.635
Linseed oil meal	9.305	35.922	31.191	6.391	11.329	5.862	1.1101	0.256	0.366	0.493	0.413	0.086	0.713
Wheat middlings	10.915	18.859	54.921	5.203	5.977	4.125	1.022	0.166	0.096	0.383	0.234	0.026	0.877
Meat meal	9.500	58.302	3.236	9.193	4.339	15.430	0.544	1.656	2.934	0.144	0.605	2.432	1.619
Skim milk	90.410	3.211	5.520	0.177	.....	0.687	0.122	0.047	0.128	0.014	0.034	0.091	0.094
Rice polish	11.127	12.475	53.296	12.770	3.200	7.132	1.1370	0.1100	0.0267	0.6585	0.168	0.134	1.497
Wheat bran	10.020	15.750	55.300	4.260	8.620	6.060	1.820	0.201	0.125	0.531	0.267	0.090	1.110
Salt	0.000	......	......	.....	......	......	0.000	38.220	0.240	0.000	0.160	59.130	0.000

Composition of Foods—Dry Basis

Foods	Moisture	Protein (Nx6.25)	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
Corn	......	10.130	80.769	4.519	3.172	1.410	0.396	0.030	0.014	0.126	0.171	0.073	0.303
Soy beans	......	43.952	25.152	19.937	5.393	5.566	2.140	0.615	0.224	0.255	0.454	0.036	0.686
Linseed oil meal	......	39.607	34.392	7.047	12.491	6.463	1.224	0.282	0.403	0.544	0.455	0.095	0.786
Wheat middlings	......	21.170	61.650	5.841	6.709	4.630	1.147	0.186	0.108	0.430	0.263	0.029	0.984
Meat meal	......	64.422	3.576	10.156	4.794	17.050	0.601	1.830	3.242	0.159	0.669	2.687	1.789
Skim milk	......	33.493	57.498	1.841	.....	7.168	1.272	0.488	1.336	0.146	0.357	0.953	0.979
Rice polish	......	14.036	61.097	13.243	3.600	8.024	1.279	0.124	0.030	0.741	0.189	0.151	1.684
Wheat bran	......	17.500	61.460	4.730	9.580	6.730	1.460	0.223	0.139	0.590	0.297	0.100	1.230

TABLE II. Total Foods Consumed—Grams Fresh Basis.

Periods	Foods	Pig I	Pig II	Pig III	Pig IV	Pig V
I 12 days	Corn	16567	24862	20655	14720	22749
	Salt	64.968	97.500	81.000	57.724	89.211
II 10 days	Corn	10459	17266	14942	10973	14219
	Soy beans	2092	3453	2988	2195	2844
	Salt	49.219	81.250	70.313	51.641	66.914
III 10 days	Corn	13945	19257	17266	13281	15772
	Linseed oil meal	2789	3852	3453	2656	3154
	Salt	65.625	90.625	81.250	62.500	74.219
IV 10 days	Corn	10133	11713	12298	10442	10949
	Wheat middlings	7645	8836	9277	7878	8259
	Salt	69.719	80.586	84.609	71.842	75.324
V 10 days	Corn	14995	20393	18219	15448	16209
	Meat meal	1500	2039	1822	1545	1621
	Salt	64.688	87.969	78.593	66.640	69.922
VI 10 days	Corn	15599	19145	18687	13866	17113
	Skim milk	31751	38968	38036	28224	34833
	Salt	61.172	75.078	73.277	54.375	67.109
VII 10 days	Corn	15599	19145	18687	13866	17113
	Salt	61.172	75.078	73.281	54.375	67.109
VIII 10 days	Rice polish	11699	......	......	10399	11206
	Wheat bran	3900	......	......	3467	3735
	Salt	61.172	......	......	54.375	58.594

TABLE III. Total Foods Consumed—Grams Dry Matter

Periods	Foods	Pig I	Pig II	Pig III	Pig IV	Pig V
I	Corn	14839.9	22270.1	18501.7	13185.4	20377.4
	Salt	64.968	97.500	81.000	57.724	89.211
II	Corn	9354.0	15441.8	13363.4	9813.7	12716.8
	Soy beans	1937.5	3198.0	2767.3	2032.9	2634.0
	Salt	49.219	81.250	70.313	51.641	66.914
III	Corn	12480.8	17235.0	15453.1	11886.5	14115.9
	Linseed oil meal	2529.5	3493.6	3131.7	2408.9	2860.5
	Salt	65.625	90.625	81.250	62.500	74.219
IV	Corn	9007.2	10411.7	10931.7	9281.9	9732.6
	Wheat middlings	6810.5	7871.6	8264.4	7018.1	7357.5
	Salt	69.719	80.586	84.609	71.842	75.324
V	Corn	13298.3	18085.5	16157.5	13700.1	14375.0
	Meat meal	1357.5	1845.3	1649.0	1398.2	1467.0
	Salt	64.688	87.969	78.593	66.640	69.922
VI	Corn	13834.0	16978.7	16572.6	12297.1	15176.7
	Skim milk	3044.9	3737.0	3647.7	2706.7	3340.5
	Salt	61.172	75.078	73.277	54.375	67.109
VII	Corn	13834.0	16978.7	16572.6	12297.1	15176.7
	Salt	61.172	75.078	73.281	54.375	67.109
VIII	Rice polish	10397.3	....	....	9241.9	9959.1
	Wheat bran	3509.2	....	....	3119.6	3360.8
	Salt	61.172	....	....	54.375	58.594

TABLE IV. Total Food Constituents—Grams Dry Matter.

Period No.	Pig No.	Protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
I	1	1503.3	11986.0	670.6	470.7	209.2	58.766	29.283	2.234	18.698	25.480	49.246	44.965
	2	2256.0	17987.3	1006.4	706.4	314.0	88.190	43.946	3.352	28.060	38.238	73.909	67.478
	3	1874.2	14943.6	836.1	586.9	260.9	73.267	36.509	2.784	23.312	31.768	61.401	56.060
	4	1335.7	10649.7	595.8	418.2	185.9	52.214	26.018	1.985	16.614	22.639	43.757	39.952
	5	2064.2	16458.6	920.9	646.4	287.3	80.695	40.213	3.067	25.676	34.988	67.632	61.744
II	1	1799.2	8042.4	809.0	401.2	239.7	78.506	33.534	5.768	16.727	24.870	36.629	41.634
	2	2969.9	13276.6	1335.4	662.3	395.7	129.584	55.355	9.521	27.612	41.054	60.467	68.727
	3	2570.0	11489.5	1155.6	573.1	342.4	112.139	47.902	8.239	23.895	35.528	52.327	59.475
	4	1887.6	8437.7	848.8	420.9	251.6	82.366	35.183	6.052	17.549	26.093	38.431	43.682
	5	2445.9	10933.7	1099.8	545.5	325.9	106.727	45.589	7.841	22.740	33.811	49.797	56.601
III	1	2266.2	10950.5	742.3	711.9	339.5	80.385	35.969	12.099	29.486	32.956	50.318	57.699
	2	3129.6	15122.0	1025.0	983.1	468.8	111.013	49.660	16.710	40.722	45.513	69.488	79.680
	3	2805.8	13558.4	919.0	881.4	420.3	99.527	44.521	14.979	36.507	40.804	62.299	71.483
	4	2158.2	10429.3	707.0	677.9	323.3	76.556	34.247	11.522	28.081	31.386	47.921	54.950
	5	2562.8	12385.1	839.8	805.1	383.9	90.912	40.668	13.682	33.346	37.273	56.908	65.254
IV	1	2354.2	11473.7	804.8	742.6	442.3	113.785	42.018	8.783	40.634	33.426	49.775	94.244
	2	2721.1	13262.2	930.3	858.4	511.3	131.517	48.565	10.152	46.967	38.635	57.535	109.004
	3	2857.0	13924.4	976.7	901.3	436.7	138.063	50.990	10.659	49.311	40.563	60.406	114.445
	4	2426.0	11823.5	829.3	765.2	163.4	117.254	43.297	9.051	41.873	34.445	51.291	97.182
	5	2543.5	12406.8	869.6	802.3	171.3	122.932	45.384	9.490	43.900	36.114	53.778	101.888
V	1	2221.6	10789.4	738.9	486.9	419.0	60.820	53.555	46.027	18.924	31.926	84.434	64.580
	2	3020.9	14673.5	1004.7	662.2	569.6	82.709	72.817	62.568	25.722	43.412	114.801	87.811
	3	2699.1	13109.3	897.7	591.6	509.4	73.894	65.062	55.912	22.980	38.787	102.576	78.458
	4	2288.5	11115.4	761.1	501.6	431.6	62.665	55.167	47.408	19.485	32.888	86.975	66.525
	5	2401.3	11663.0	798.6	526.3	452.8	65.742	57.883	49.741	20.446	34.507	91.267	69.801
VI	1	2421.2	12924.4	681.3	438.8	413.4	93.514	42.389	42.764	21.877	34.624	75.288	71.727
	2	2971.5	15862.2	836.1	538.6	507.3	114.771	52.026	52.483	26.849	42.490	92.402	88.030
	3	2900.5	15482.9	816.1	525.7	495.2	112.026	50.779	51.229	26.207	41.478	90.190	85.926
	4	2152.2	11488.5	605.5	390.1	367.4	83.126	37.680	38.015	19.446	30.778	66.924	63.759
	5	2656.2	14178.8	747.3	481.4	453.4	102.591	46.504	46.915	24.000	37.965	82.596	78.688
VII	1	1401.4	11173.6	625.2	438.8	195.1	54.783	27.530	2.084	17.431	23.754	46.270	41.917
	2	1719.9	13713.5	767.3	538.7	239.3	67.236	33.789	2.557	21.393	29.154	56.789	51.446
	3	1678.8	13385.5	748.9	525.7	233.7	65.627	32.980	2.496	20.881	28.456	55.429	50.215
	4	1245.7	9932.2	555.7	390.1	173.4	48.696	24.471	1.852	15.494	21.115	41.129	37.260
	5	1537.4	12258.1	685.8	481.4	214.0	60.100	30.202	2.286	19.123	26.059	50.761	45.985
VIII	1	2073.5	8509.2	1542.9	710.5	1070.5	184.215	44.098	8.145	97.748	30.171	55.380	218.173
	4	1843.1	7563.8	1371.5	631.6	951.6	163.760	39.199	7.240	86.888	26.819	49.228	194.005
	5	1986.0	8150.2	1477.9	680.5	1025.3	176.446	42.239	7.801	93.626	28.899	53.046	209.049

TABLE V. Total Urinary Constituents—Grams.

Period No.	Pig No.	Total nitrogen	Ammonia nitrogen	Creatinin	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
II	1	152.120	16.486	8.278	33.101	9.350	0.752	2.109	12.330	31.332	10.892
	2	234.024	28.307	10.421	40.170	11.971	1.151	3.017	19.321	47.028	14.915
	3	209.996	22.086	10.277	61.968	17.861	0.967	2.456	17.743	40.631	13.789
	4	148.065	25.200	6.974	50.199	13.827	0.803	1.256	12.974	31.577	8.765
	5	189.716	21.809	8.827	54.038	9.663	0.940	2.254	15.701	37.444	12.068
III	1	194.972	18.842	11.933	44.003	20.519	0.957	4.869	12.394	40.880	10.809
	2	263.476	26.419	16.390	56.737	21.544	1.721	6.732	21.559	54.905	12.772
	3	254.500	23.987	14.561	55.743	25.704	1.055	6.126	18.065	52.780	14.175
	4	180.724	29.010	11.338	37.924	19.251	0.931	3.490	10.231	38.373	8.130
	5	221.947	22.680	12.959	44.351	22.609	0.776	4.290	18.119	44.556	11.678
IV	1	190.637	25.866	15.713	55.855	25.681	2.092	4.414	13.014	46.331	33.888
	2	196.557	33.559	21.701	58.293	18.432	1.964	5.925	16.820	52.170	35.369
	3	246.682	36.208	21.257	68.105	26.321	2.376	5.960	18.636	56.842	42.281
	4	191.380	42.661	14.053	62.686	19.658	1.461	4.805	20.450	47.473	38.458
	5	214.910	30.114	17.798	57.461	18.538	1.192	5.277	15.959	48.128	37.683
V	1	188.043	24.818	19.022	36.535	52.553	2.114	3.783	10.457	85.374	20.074
	2	288.410	49.470	23.500	48.300	54.216	2.925	3.917	9.582	110.078	23.946
	3	263.857	30.234	22.939	47.107	59.482	2.154	3.963	10.209	102.776	25.246
	4	192.528	45.822	17.026	38.516	50.145	2.053	2.495	16.047	88.039	17.468
	5	200.727	24.360	20.997	37.861	49.113	1.818	2.889	11.832	49.964	19.537
VI	1	201.734	19.741	20.565	72.654	31.871	1.702	4.789	13.875	68.614	24.387
	2	296.737	34.857	24.925	90.297	31.856	2.766	4.823	22.607	82.972	27.261
	3	305.631	22.063	23.290	91.549	39.772	1.978	5.062	20.275	83.367	29.491
	4	205.344	35.788	18.157	69.133	24.481	1.643	2.351	12.238	61.966	19.171
	5	254.890	21.801	22.501	79.137	28.380	1.225	3.969	19.083	30.069	24.571
VII	1	143.568	19.375	24.296	28.198	28.620	1.190	2.978	12.374	42.681	17.262
	2	157.498	26.683	29.670	27.167	24.005	1.785	2.995	14.809	50.547	15.433
	3	165.607	18.289	28.475	30.073	32.408	1.394	3.163	15.864	49.865	18.009
	4	130.905	32.735	20.689	27.161	21.506	1.347	2.154	13.325	36.727	15.266
	5	162.278	18.852	26.390	30.691	28.117	0.879	2.607	13.697	45.591	17.495
VIII	1	167.079	24.248	28.587	162.019	11.479	1.159	5.268	12.023	37.887	9.374
	4	140.118	41.243	24.164	140.529	12.380	1.324	3.734	8.116	38.802	7.543
	5	168.537	22.909	28.984	149.298	13.426	0.833	4.092	9.928	34.574	8.968

TABLE VI. Total Weight of Feces—Grams as Sampled*

Pig No.	Period I	Period II	Period III	Period IV	Period V	Period VI	Period VII	Period VIII
I	1794	3305	5384	8098	4564	3934	3592	9566
II	3000	7745	9418	10954	7324	5685	5631	....
III	2330	5557	6594	8982	6036	5105	4803	....
IV	1569	4025	5795	8315	5647	3828	3556	9971
V	2510	5383	6623	8635	5000	4616	4129	9484

*The feces from Period I were dried in an air oven at 50° and sampled dry; all others were refrigerated and were then sampled moist.

TABLE VII. Feces Constituents—Percent, As Sampled.

Period No.	Pig No.	Total protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen	Metabolic nitrogen	Metabolic protein	Indigestible protein
1	1	16.625	51.833	12.911	6.047	8.711	1.120	0.205	0.423	0.955	0.255	0.011	1.869	2.660	1.609	10.056	6.569
	2	17.363	51.651	13.318	5.753	8.201	1.115	0.176	0.445	0.942	0.273	0.031	1.681	2.778	2.206	13.788	3.575
	3	16.975	51.271	13.637	5.825	8.616	1.028	0.402	0.471	0.980	0.250	0.009	1.824	2.716	1.805	11.281	5.694
	4	15.719	51.465	13.859	5.972	9.017	0.938	0.307	0.561	1.043	0.236	0.026	1.869	2.515	1.604	10.025	5.694
	5	17.425	49.939	13.776	5.980	8.647	1.092	0.221	0.407	0.975	0.259	0.031	1.755	2.788	1.803	11.269	6.156
2	1	9.306	16.388	6.033	4.721	4.036	0.487	0.114	0.230	0.457	0.147	0.005	0.801	1.489	0.911	5.694	3.612
	2	8.613	10.708	5.624	3.673	3.150	0.507	0.096	0.162	0.312	0.114	0.006	0.593	1.378	0.895	5.594	3.019
	3	7.169	13.405	4.893	4.137	3.337	0.508	0.067	0.163	0.368	0.107	0.004	0.689	1.147	0.760	4.750	2.419
	4	8.525	14.122	4.504	4.356	3.210	0.395	0.159	0.183	0.390	0.124	0.005	0.731	1.364	0.882	5.513	3.012
	5	8.506	12.388	6.265	4.395	3.419	0.538	0.070	0.156	0.366	0.120	0.005	0.670	1.361	0.864	5.400	3.106
3	1	7.825	15.747	5.554	6.913	4.229	0.465	0.129	0.137	0.474	0.129	0.008	0.772	1.252	0.724	4.525	3.300
	2	6.763	13.412	4.111	5.668	3.469	0.435	0.115	0.123	0.375	0.107	0.005	0.641	1.082	0.660	4.125	2.638
	3	6.788	15.436	4.862	7.085	4.133	0.464	0.102	0.137	0.474	0.120	0.003	0.778	1.086	0.597	3.731	3.057
	4	7.050	15.305	4.218	6.077	3.914	0.411	0.114	0.153	0.435	0.120	0.006	0.746	1.128	0.716	4.475	2.575
	5	6.325	15.043	4.449	6.522	4.146	0.523	0.093	0.143	0.453	0.126	0.010	0.750	1.172	0.757	4.731	2.594
4	1	5.513	15.388	2.937	5.876	3.275	0.502	0.166	0.065	0.432	0.106	0.006	0.635	0.882	0.577	3.606	1.907
	2	5.381	14.084	2.548	5.073	3.021	0.495	0.108	0.069	0.362	0.096	0.029	0.572	0.861	0.587	3.669	1.712
	3	5.313	16.153	3.376	6.553	3.561	0.594	0.050	0.067	0.488	0.105	0.015	0.689	0.850	0.546	3.413	1.900
	4	5.169	15.361	2.499	5.894	3.160	0.424	0.133	0.075	0.430	0.097	0.006	0.579	0.827	0.528	3.300	1.869
	5	4.906	15.149	2.704	6.113	3.268	0.497	0.122	0.093	0.445	0.097	0.016	0.603	0.785	0.502	3.138	1.768
5	1	10.681	15.543	3.401	5.406	3.751	0.222	0.204	0.301	0.342	0.180	0.006	0.606	1.709	0.955	5.969	4.712
	2	10.731	13.450	3.613	4.753	3.695	0.303	0.184	0.258	0.306	0.174	0.007	0.604	1.717	1.093	6.831	3.900
	3	10.994	14.650	3.103	5.519	3.730	0.288	0.158	0.320	0.347	0.183	0.005	0.609	1.759	0.952	5.950	5.044
	4	10.056	13.655	2.819	4.957	3.607	0.252	0.200	0.305	0.320	0.170	0.006	0.609	1.609	0.918	5.738	4.318
	5	10.675	14.994	3.239	5.635	4.025	0.290	0.187	0.353	0.367	0.190	0.007	0.637	1.708	0.996	6.225	4.450
6	1	7.244	19.895	5.188	4.645	3.661	0.335	0.200	0.284	0.410	0.112	0.003	0.709	1.159	0.717	4.481	2.763
	2	6.344	17.335	4.085	3.994	3.547	0.366	0.170	0.307	0.361	0.100	0.002	0.705	1.015	0.694	4.338	2.006
	3	5.906	16.001	4.302	4.150	3.506	0.356	0.134	0.282	0.387	0.090	0.002	0.714	0.945	0.579	3.619	2.287
	4	6.419	16.600	4.054	4.250	3.743	0.287	0.190	0.318	0.412	0.101	0.002	0.765	1.027	0.637	3.981	2.438
	5	7.144	15.949	4.747	3.863	3.807	0.375	0.132	0.294	0.409	0.118	0.004	0.742	1.143	0.700	4.375	2.769
7	1	5.893	17.441	5.833	4.360	3.397	0.452	0.098	0.120	0.423	0.098	0.005	0.677	0.943	0.512	3.200	2.693
	2	6.063	15.512	5.250	3.856	3.094	0.440	0.132	0.113	0.354	0.092	0.008	0.616	0.970	0.663	4.144	1.919
	3	5.450	16.686	5.387	4.398	3.231	0.422	0.111	0.117	0.401	0.088	0.005	0.649	0.872	0.374	2.338	3.112
	4	5.281	17.538	5.051	4.524	3.227	0.383	0.156	0.132	0.405	0.067	0.007	0.623	0.845	0.494	3.088	2.193
	5	5.831	17.454	5.777	4.420	3.435	0.459	0.119	0.122	0.426	0.101	0.010	0.673	0.933	0.592	3.700	2.131
8	1	4.506	11.592	3.066	5.727	6.781	0.416	0.152	0.111	1.046	0.086	0.006	1.588	0.721	0.413	2.581	1.925
	4	4.206	10.713	2.978	4.346	6.245	0.405	0.106	0.123	0.902	0.080	0.005	1.455	0.673	0.419	2.619	1.587
	5	4.038	12.804	3.148	4.708	6.871	0.488	0.075	0.126	1.027	0.088	0.007	1.589	0.646	0.416	2.600	1.488

TABLE VIII. Total Feces Constituents—Grams

Period No.	Pig No.	Total weight feces	Indigestible protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen	Total protein	Metabolic protein
I	1	1794	117.848	929.884	231.623	108.483	156.275	20.093	3.678	7.589	17.133	4.575	.197	33.530	47.720	298.252	180.405
	2	3000	107.250	1549.530	399.540	172.590	246.030	33.450	5.280	13.350	28.260	8.190	.930	50.430	83.340	520.899	413.640
	3	2330	132.670	1194.614	317.742	135.723	200.753	23.952	9.367	10.974	22.834	5.825	.210	42.499	63.283	395.518	262.847
	4	1569	89.339	807.486	217.428	93.701	141.477	14.717	4.817	8.802	16.365	3.687	.408	29.325	39.460	246.631	157.292
	5	2510	154.516	1253.469	345.778	150.098	217.040	27.409	5.547	10.216	24.473	6.501	.778	44.051	69.979	437.368	282.852
II	1	3305	119.377	541.623	199.391	156.029	133.390	16.095	3.768	7.602	15.104	4.858	.165	26.473	49.211	307.563	188.187
	2	7745	233.822	829.335	435.579	284.474	243.968	39.267	7.435	12.547	24.164	8.829	.465	45.928	106.726	667.077	433.255
	3	5557	134.424	744.916	271.904	229.893	185.437	28.230	4.835	9.068	20.450	5.946	.222	38.288	63.739	398.381	263.958
	4	4025	121.233	568.411	181.286	175.329	129.203	15.899	6.400	7.366	15.698	4.991	.201	29.423	54.901	343.131	221.898
	5	5383	167.196	666.846	337.245	236.583	184.045	28.961	3.768	8.397	19.702	6.460	.269	36.066	73.263	457.878	290.682
III	1	5384	177.672	847.818	299.027	372.196	227.689	25.036	6.945	7.376	25.520	6.945	.431	41.564	67.408	421.298	243.626
	2	9418	248.447	1263.142	387.174	533.812	326.710	40.968	10.831	11.584	35.318	10.077	.471	60.369	101.903	636.939	388.493
	3	6594	201.579	1017.850	320.600	467.185	272.530	30.596	6.726	9.034	31.256	7.913	.198	51.301	71.611	447.601	246.022
	4	5795	149.221	886.925	244.433	352.162	226.816	23.817	6.606	8.866	25.208	6.954	.348	43.231	65.368	408.548	259.326
	5	6623	171.801	996.298	294.657	431.952	274.590	34.638	6.159	9.471	30.002	8.345	.662	49.673	77.622	485.135	313.334
IV	1	8098	154.429	1246.120	237.838	475.838	265.210	40.652	13.443	5.264	34.983	8.503	.486	51.422	71.424	446.443	292.014
	2	10954	187.532	1542.761	279.108	555.696	330.920	54.222	11.830	7.558	39.653	10.516	3.177	62.657	94.314	589.435	401.902
	3	8982	170.658	1450.862	303.232	588.590	319.849	53.353	4.491	7.814	43.832	9.431	1.347	61.886	76.347	477.214	306.556
	4	8315	155.407	1277.267	207.792	490.086	262.754	35.257	11.059	6.236	35.575	8.066	.499	48.144	68.765	429.802	274.395
	5	8635	152.667	1308.116	233.490	527.858	282.192	42.916	10.535	8.031	38.426	8.376	1.382	52.069	67.785	423.633	270.966
V	1	4564	215.056	709.383	155.222	246.730	171.196	10.132	9.311	13.738	15.609	8.215	.274	27.658	77.999	487.481	272.425
	2	7324	285.636	985.078	264.616	348.110	270.622	22.192	13.476	18.896	22.411	12.744	.513	44.237	125.753	785.938	500.302
	3	6066	306.978	891.599	188.849	335.886	227.008	17.528	9.616	19.475	21.118	11.137	.304	37.064	107.063	669.095	362.117
	4	5647	243.837	771.098	159.189	279.922	203.687	14.230	11.294	17.223	18.070	9.600	.339	34.390	90.860	567.862	324.025
	5	5000	222.500	749.760	161.900	281.750	201.250	14.500	9.350	17.650	18.350	9.500	.350	31.850	85.400	533.750	311.250
VI	1	3934	108.696	782.669	204.096	182.734	144.024	13.179	7.868	11.173	16.129	4.406	.118	27.892	45.595	284.979	176.283
	2	5685	114.041	985.495	232.232	227.059	201.647	20.807	9.665	17.453	20.523	5.685	.114	40.079	57.703	360.656	246.615
	3	5105	116.751	816.851	219.617	211.858	178.930	18.174	6.841	14.396	19.756	4.595	.102	36.450	48.242	301.501	184.750
	4	3828	93.327	635.448	155.187	162.690	143.282	10.986	7.273	12.173	15.771	3.866	.077	29.284	39.314	245.719	152.393
	5	4616	127.817	736.206	219.122	178.316	175.731	17.310	6.093	13.571	18.879	5.447	.185	34.251	52.761	329.767	201.950
VII	1	3592	96.733	626.481	209.621	156.611	122.020	16.236	3.448	4.310	15.194	3.520	.180	24.318	33.873	211.677	114.944
	2	5631	108.059	873.481	295.628	217.131	174.223	24.776	7.443	6.363	19.934	5.181	.440	34.687	54.621	341.408	233.349
	3	4803	149.469	801.429	258.738	211.236	155.185	20.269	5.331	5.690	19.260	4.227	.260	31.171	41.882	261.764	112.294
	4	3556	77.983	623.651	179.614	160.873	114.752	13.619	5.547	4.694	14.402	3.094	.249	22.154	30.048	187.792	109.809
	5	4129	87.989	720.676	238.532	182.502	141.831	18.952	4.914	5.037	17.590	4.170	.413	27.788	38.524	240.762	152.773
VIII	1	9566	184.146	1108.891	293.294	547.845	648.670	39.795	14.540	10.618	100.060	8.227	.574	151.908	68.971	431.044	246.898
	4	9971	158.240	1068.193	296.936	433.340	622.689	40.383	10.569	12.264	89.938	7.977	.499	145.078	67.105	419.380	261.140
	5	9484	136.380	1214.331	298.556	446.507	651.646	46.282	7.113	11.950	97.401	8.156	.664	150.701	61.267	382.964	246.584

TABLE IX. Coefficients of Digestibility of Foodstuffs With Swine

Period No.	Foodstuff	Pig No.	Protein	Nitrogen-free extract	Ether extract	Crude fiber
I	Corn meal	1	92.16	92.24	65.46	76.95
		2	95.25	91.39	60.30	75.57
		3	92.92	92.01	62.00	76.87
		4	93.31	92.42	63.51	77.69
		5	92.51	92.38	62.45	76.78
		Ave.	93.23	92.09	62.74	76.75
VII	Corn meal	1	93.10	94.39	66.49	64.31
		2	93.72	93.63	61.47	59.69
		3	91.10	94.01	65.45	59.82
		4	93.74	93.72	67.68	58.76
		5	94.28	94.12	65.22	62.09
		Ave.	93.19	93.97	65.26	60.93
Ave. I and VII	Corn meal	1	92.63	93.32	65.98	70.63
		2	94.49	92.51	60.89	67.63
		3	92.01	93.01	63.73	68.35
		4	93.53	93.07	65.60	68.18
		5	93.40	93.25	63.84	69.44
		Ave.	93.21	93.03	64.01	68.85
II	Soybeans	1	94.18	92.43	85.61	34.08
		2	89.50	113.04	74.49	27.00
		3	97.84	101.38	90.42	35.84
		4	93.63	96.26	92.91	30.41
		5	92.09	103.99	75.35	20.26
		Ave.	93.45	101.42	83.76	29.52
III	Linseed oil meal	1	91.56	79.95	39.90	19.01
		2	89.00	81.65	66.46	18.23
		3	93.83	86.50	69.49	20.24
		4	92.53	73.26	64.86	22.83
		5	93.17	76.96	68.31	17.41
		Ave.	92.02	79.66	61.81	19.54
IV	Wheat middlings	1	93.95	81.90	75.02	14.22
		2	92.23	81.19	79.32	15.02
		3	95.30	83.64	74.90	13.65
		4	93.63	82.49	84.50	15.80
		5	94.38	83.08	82.68	12.17
		Ave.	93.90	82.46	79.16	14.17
V	Meat meal	1	86.76	(116.72)	(135.71)	(—88.71)
		2	84.46	(265.19)	(129.36)	(—83.61)
		3	83.41	(134.94)	(145.37)	(—119.57)
		4	82.90	(91.47)	(137.87)	(—111.39)
		5	86.63	(164.78)	(148.98)	(—102.55)
		Ave.	84.83	(154.62)	(139.45)	(—101.15)
VI	Skim milk	1	99.47	(97.93)	(115.32)	(—)
		2	98.46	(101.94)	(198.63)	(—)
		3	101.42	(105.66)	(177.39)	(—)
		4	98.60	(103.40)	(172.24)	(—)
		5	97.64	(104.75)	(146.93)	(—)
		Ave.	99.12	(102.74)	(162.10)	(—)

TABLE X. Average Daily Mineral Intake with Balance of Acid and Basic Elements—Grams

Period and Food	Pig No.	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Excess acid (c. c. normal sol.)	Ammonia nitrogen in urine	Creatinin in urine
I Corn Salt	I	4.897	2.440	0.186	1.558	2.123	4.104	3.747	.....	1.712	0.819
	II	7.349	3.662	0.279	2.338	3.187	6.159	5.623	.....	2.599	1.162
	III	6.105	3.042	0.232	1.942	2.647	5.117	4.672	.....	1.954	0.957
	IV	4.351	2.168	0.165	1.384	1.887	3.646	3.329	.....	2.637	0.766
	V	6.724	3.351	0.255	2.139	2.916	5.636	5.145	.....	1.848	0.970
	Ave.	5.885	2.933	0.223	1.872	2.548	4.932	4.503	145.8	2.150	0.935
II Corn Soybeans Salt	I	7.851	3.353	0.577	1.673	2.487	3.663	4.168	.....	1.649	0.828
	II	12.968	5.536	0.952	2.761	4.105	6.047	6.873	.....	2.831	1.042
	III	11.214	4.790	0.824	2.390	3.553	5.233	5.948	.....	2.209	1.028
	IV	8.237	3.518	0.605	1.755	2.609	3.843	4.368	.....	2.520	0.697
	V	10.673	4.559	0.784	2.274	3.381	4.980	5.660	.....	2.181	0.883
	Ave.	10.187	4.351	0.748	2.171	3.227	4.753	5.402	18.9	2.278	0.896
III Corn Linseed oil meal Salt	I	8.039	3.596	1.210	2.949	3.296	5.032	5.770	.....	1.884	1.193
	II	11.101	4.966	1.671	4.072	4.551	6.949	7.968	.....	2.642	1.639
	III	9.953	4.452	1.498	3.651	4.080	6.230	7.148	.....	2.399	1.456
	IV	7.656	3.425	1.152	2.808	3.139	4.792	5.495	.....	2.901	1.134
	V	9.091	4.067	1.368	3.335	3.727	5.691	6.525	.....	2.268	1.296
	Ave.	9.168	4.101	1.380	3.363	3.759	5.739	6.581	63.2	2.419	1.344
IV Corn Wheat middlings Salt	I	11.379	4.202	0.878	4.063	3.343	4.978	9.424	.....	2.587	1.571
	II	13.152	4.857	1.015	4.697	3.864	5.754	10.900	.....	3.356	2.170
	III	13.808	5.099	1.066	4.931	4.056	6.041	11.445	.....	3.621	2.126
	IV	11.725	4.330	0.905	4.187	3.445	5.129	9.718	.....	4.266	1.405
	V	12.293	4.538	0.949	4.390	3.611	5.378	10.189	.....	3.011	1.780
	Ave.	12.471	4.605	0.963	4.454	3.664	5.456	10.335	116.3	3.368	1.810
V Corn Meat meal Salt	I	6.062	5.356	4.603	1.892	3.193	8.443	6.458	.....	2.482	1.902
	II	8.271	7.282	6.257	2.572	4.341	11.480	8.781	.....	4.947	2.350
	III	7.389	6.506	5.591	2.298	3.879	10.256	7.846	.....	3.023	2.294
	IV	6.266	5.517	4.741	1.949	3.289	8.698	6.653	.....	4.562	1.708
	V	6.574	5.788	4.974	2.045	3.451	9.126	6.980	.....	2.436	2.010
	Ave.	6.916	6.090	5.233	2.151	3.631	9.601	7.344	92.2	3.494	2.070
VI Corn Skim milk Salt	I	9.351	4.239	4.276	2.188	3.462	7.529	7.173	.....	1.974	2.057
	II	11.477	5.203	5.248	2.685	4.248	9.240	8.803	.....	3.496	2.493
	III	11.203	5.078	5.123	2.621	4.148	9.019	8.593	.....	2.208	2.329
	IV	8.313	3.768	3.802	1.945	3.078	6.692	6.376	.....	3.579	1.816
	V	10.259	4.650	4.692	2.400	3.799	8.260	7.869	.....	2.180	2.250
	Ave.	10.121	4.588	4.628	2.368	3.747	8.148	7.763	81.0	2.685	2.189
VII Corn Salt	I	5.478	2.753	0.208	1.743	2.375	4.627	4.192	.....	1.938	2.430
	II	6.724	3.379	0.256	2.139	2.915	5.679	5.145	.....	2.668	2.967
	III	6.563	3.298	0.250	2.088	2.846	5.543	5.022	.....	1.829	2.848
	IV	4.870	2.447	0.185	1.549	2.112	4.113	3.726	.....	3.274	2.070
	V	6.010	3.020	0.229	1.912	2.606	5.076	4.599	.....	1.885	2.639
	Ave.	5.929	2.979	0.226	1.886	2.571	5.008	4.537	147.0	2.319	2.591
VIII Rice polish Wheat bran Salt	I	18.422	4.410	0.815	9.775	3.017	5.538	21.817	.....	2.425	2.859
	IV	16.376	3.920	0.724	8.869	2.682	4.923	19.401	.....	4.124	2.416
	V	17.645	4.224	0.780	9.363	2.890	5.305	20.905	.....	2.291	2.898
	Ave.	17.481	4.185	0.773	9.276	2.863	5.255	20.708	232.8	2.947	2.725

TABLE XI. Mineral Elements in Average Daily Rations Computed to Cubic Centimeters of Normal Solution.

Period No.	Average daily rations Grams, Fresh Basis	Potassium	Sodium	Calcium	Magnesium	Total base	Sulphur	Chlorine	Phosphorus	Total acid	Excess acid
I	Corn .... 1659.2 Salt 6.507	150.5	127.2	11.1	153.9	442.7	158.9	139.1	290.5	588.5	145.8
II	Corn .... 1357.2 Soy beans .... 271.4 Salt 6.387	260.5	188.7	37.3	178.5	665.0	201.3	134.1	348.5	683.9	18.9
III	Corn .... 1590.4 Linseed oil meal .... 318.1 Salt 7.484	234.5	177.9	68.8	276.6	757.8	234.5	161.9	424.6	821.0	63.2
IV	Corn .... 1110.7 Wheat middlings .... 837.9 Salt 7.642	319.0	199.7	48.0	366.3	933.0	228.6	153.9	666.8	1049.3	116.3
V	Corn .... 1705.3 Meat meal .... 170.5 Salt 7.356	176.9	264.2	261.0	176.9	879.0	226.5	270.9	473.8	971.2	92.2
VI	Corn .... 1698.2 Skim milk .... 3436.2 Salt 6.620	258.8	199.0	230.8	194.7	883.3	233.7	229.8	500.8	964.3	81.0
VII	Corn .... 1698.2 Salt 6.620	151.6	129.2	11.3	155.1	447.2	160.3	141.2	292.7	594.2	147.0
VIII	Rice polish .... 1110.1 Wheat bran .... 370.1 Salt 5.805	447.1	181.5	38.6	762.8	1430.0	178.6	148.2	1336.0	1662.8	232.8

TABLE XII. Relation of Magnesium to Calcium Metabolism

Period No.	Ca Retention Grams	Ca Intake Grams	Ratio of Ca : Mg intake*	Excess mineral acid per day (c. c. normal sol.)	Urinary ammonia per day (N) Grams
VIII	−0.498	0.773	0.0833	232.8	2.947
VII	−0.427	0.226	0.120	147.0	2.425
IV	+0.083	0.963	0.216	116.3	3.368
II	−0.243	0.748	0.344	18.9	2.278
III	+0.344	1.380	0.410	63.2	2.419
VI	+3.047	4.628	1.954	81.0	2.685
V	+3.282	5.233	2.432	92.2	3.494

*In terms of chemically equivalent amounts.

TABLE XIII. Slaughter Test—Animals Arranged in Order of Creatinin Elimination—Kg.

No. of animal	Live weight	Dressed carcass	Flesh	Blood	Bones	Hoofs	Heart	Lungs	Liver	Kidneys	Spleen	Brain
II	121.0	102.7	91.4	4.288	6.454	0.310	0.316	0.407	1.255	0.201	0.120	0.110
III	111.0	94.6	83.9	3.733	6.242	0.294	0.261	0.525	1.155	0.177	0.128	0.108
V	108.6	92.1	81.9	3.568	.....	0.284	0.299	0.449	1.062	0.184	0.121	0.111
I	94.0	78.7	70.1	3.275	5.394	0.214	0.247	0.355	1.005	0.160	0.093	0.115
IV	89.0	75.0	66.7	3.024	.....	0.252	0.280	0.419	1.124	0.165	0.096	0.104

TABLE XIV. PERIOD II: Average Daily Rations and Mineral Balances—Grams.

Pig No.	Approximate live weight Kg.	Average daily rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	43	Corn	1045.9	7.851	3.353	0.577	1.673	2.457	3.663	4.163	28.787
		Soy beans	209.2	3.310	0.935	0.075	0.211	1.233	3.133	1.069	15.212
		Salt	4.922	1.610	0.377	0.760	1.510	0.456	0.017	2.647	4.921
		Water	2967	+2.931	+2.041	−0.258	−0.048	+0.768	+0.513	+0.427	+8.654
II	64	Corn	1726.6	12.958	5.536	0.952	2.761	4.105	6.047	6.873	47.518
		Soy beans	345.3	4.017	1.197	0.115	0.302	1.932	4.703	1.492	23.402
		Salt	8.125	3.927	0.744	1.255	2.416	0.883	0.047	4.593	10.673
		Water	4019	+5.014	+3.595	−0.418	+0.043	+1.290	+1.297	+0.788	+13.443
III	55	Corn	1494.2	11.214	4.790	0.824	2.390	3.553	5.233	5.948	41.120
		Soy beans	298.8	6.196	1.786	0.097	0.246	1.774	4.063	1.379	21.000
		Salt	7.031	2.823	0.484	0.906	2.045	0.595	0.022	3.829	6.374
		Water	4074	+2.195	+2.520	−0.179	+0.099	+1.184	+1.148	+0.740	+13.746
IV	42	Corn	1097.3	8.237	3.518	0.605	1.755	2.609	3.843	4.368	30.201
		Soy beans	219.5	5.020	1.383	0.060	0.126	1.297	3.158	0.877	14.807
		Salt	5.164	1.590	0.640	0.737	1.570	0.499	0.020	2.942	5.490
		Water	3297	+1.627	+1.495	−0.212	+0.059	+0.813	+0.665	+0.549	+9.904
V	56	Corn	1421.9	10.673	4.559	0.784	2.274	3.381	4.980	5.660	39.134
		Soy beans	284.4	5.404	0.966	0.094	0.225	1.570	3.744	1.209	18.972
		Salt	6.691	2.896	0.377	0.840	1.970	0.646	0.027	3.607	7.326
		Water	2949	+2.373	+3.216	−0.150	+0.079	+1.165	+1.209	+0.844	+12.836

TABLE XV. PERIOD III: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily ration	*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	51	Corn 1394.5	8.039	3.596	1.210	2.949	3.296	5.032	5.770	36.259
		Linseed oil meal 278.9	4.400	2.052	0.096	0.487	1.239	4.088	1.081	19.500
		Salt 6.563	2.504	0.695	0.738	2.552	0.695	0.043	4.156	6.741
		Water 5313	+1.135	+0.849	+0.376	−0.090	+1.362	+0.901	+0.533	+10.018
II	76	Corn 1925.7	11.101	4.966	1.671	4.072	4.551	6.949	7.968	50.073
		Linseed oil meal 385.2	5.674	2.154	0.172	0.673	2.156	5.491	1.278	26.348
		Salt 9.063	4.097	1.083	1.158	3.532	1.008	0.047	6.037	10.190
		Water 6053	+1.330	+1.729	+0.341	−0.133	+1.387	+1.411	+0.653	+13.535
III	66	Corn 1726.6	9.953	4.452	1.498	3.651	4.080	6.230	7.148	44.892
		Linseed oil meal 345.3	5.574	2.570	0.106	0.613	1.807	5.278	1.418	25.450
		Salt 8.125	3.060	0.673	0.903	3.126	0.791	0.020	5.130	7.161
		Water 5935	+1.319	+1.209	+0.489	−0.088	+1.482	+0.932	+0.600	+12.281
IV	59	Corn 1328.1	7.656	3.425	1.152	2.808	3.139	4.792	5.495	34.531
		Linseed oil meal 265.6	3.792	1.925	0.093	0.349	1.023	3.837	0.813	18.072
		Salt 6.250	2.382	0.661	0.887	2.521	0.695	0.035	4.323	6.537
		Water 5212	+1.482	+0.839	+0.172	−0.062	+1.421	+0.920	+0.359	+9.922
V	67	Corn 1577.2	9.091	4.067	1.368	3.335	3.727	5.691	6.525	41.004
		Linseed oil meal 315.4	4.435	2.261	0.078	0.429	1.812	4.456	1.168	22.195
		Salt 7.422	3.464	0.616	0.947	3.000	0.835	0.066	4.967	7.762
		Water 3721	+1.192	+1.190	+0.343	−0.094	+1.080	+1.169	+0.390	+11.047

TABLE XVI. PERIOD IV: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily ration		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	60	Corn	1013.3	11.379	4.202	0.878	4.063	3.343	4.978	9.424	37.667
		Wheat middlings	764.5	5.586	2.568	0.209	0.441	1.301	4.633	3.389	19.064
		Salt	6.972	4.065	1.344	0.526	3.498	0.850	0.049	5.142	7.142
		Water	5709	+1.728	+0.290	+0.143	+0.124	+1.192	+0.296	+0.893	+11.461
II	86	Corn	1171.3	13.152	4.857	1.015	4.697	3.864	5.754	10.900	43.537
		Wheat middlings	883.6	5.829	1.843	0.196	0.593	1.682	5.217	3.537	19.656
		Salt	8.059	5.422	1.183	0.756	3.965	1.052	0.318	6.266	9.431
		Water	4476	+1.901	+1.831	+0.063	+0.139	+1.130	+0.219	+1.097	+14.450
III	75	Corn	1229.8	13.806	5.099	1.066	4.931	4.056	6.041	11.445	45.712
		Wheat middlings	927.7	6.811	2.632	0.238	0.596	1.864	5.684	4.228	24.668
		Salt	8.461	5.335	0.449	0.781	4.383	0.943	0.135	6.189	7.635
		Water	5416	+1.662	+2.018	+0.047	—0.048	+1.249	+0.222	+1.028	+13.409
IV	57	Corn	1044.2	11.725	4.330	0.905	4.187	3.445	5.129	9.718	38.816
		Wheat middlings	787.8	6.269	1.966	0.146	0.481	2.045	4.747	3.846	19.138
		Salt	7.184	3.526	1.106	0.624	3.558	0.807	0.050	4.814	6.877
		Water	5727	+1.930	+1.258	+0.135	+0.148	+0.593	+0.332	+1.058	+12.801
V	75	Corn	1094.9	12.293	4.538	0.949	4.390	3.611	5.378	10.189	40.696
		Wheat middlings	825.9	5.746	1.854	0.119	0.528	1.596	4.813	3.768	21.491
		Salt	7.532	4.292	1.064	0.803	3.843	0.838	0.138	5.209	6.779
		Water	4044	+2.255	+1.630	+0.027	+0.019	+1.177	+0.427	+1.214	+12.426

TABLE XVII. PERIOD V: Average Daily Rations and Mineral Balances—Grams.

Pig No.	Approximate live weight Kg.	Average daily ration		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	68	Corn	1499.5	6.082	5.356	4.603	1.892	3.193	8.443	6.458	35.545
		Meat meal	150.0	3.654	5.255	0.211	0.378	1.046	8.537	2.007	18.804
		Salt	6.469	1.013	0.931	1.374	1.561	0.822	0.027	2.766	7.800
		Water	5828	+1.415	−0.830	+3.018	−0.047	+1.325	−0.121	+1.685	+8.941
II	94	Corn	2039.3	8.271	7.282	6.257	2.572	4.341	11.480	8.781	48.334
		Meat meal	203.9	4.830	5.422	0.293	0.392	0.958	11.008	2.395	28.841
		Salt	8.797	2.219	1.348	1.890	2.241	1.274	0.051	4.424	12.575
		Water	3534	+1.222	+0.512	+4.074	−0.061	+2.109	+0.421	+1.962	+6.918
III	83	Corn	1821.9	7.389	6.506	5.591	2.298	3.879	10.258	7.846	43.185
		Meat meal	182.2	4.711	5.948	0.215	0.396	1.021	10.278	2.525	26.386
		Salt	7.869	1.753	0.962	1.948	2.112	1.114	0.030	3.706	10.705
		Water	5156	+0.925	−0.404	+3.428	−0.210	+1.744	−0.050	+1.615	+6.094
IV	64	Corn	1544.8	6.266	5.517	4.741	1.949	3.289	8.698	6.653	36.616
		Meat meal	154.5	3.862	5.015	0.205	0.250	1.605	8.804	1.746	19.253
		Salt	6.664	1.423	1.129	1.722	1.807	0.960	0.034	3.439	9.086
		Water	6350	+0.991	−0.627	+2.814	−0.108	+0.724	−0.140	+1.468	+8.277
V	83	Corn	1620.9	6.574	5.788	4.974	2.045	3.451	9.126	6.980	38.420
		Meat meal	162.1	3.786	4.911	0.132	0.289	1.183	4.996	1.954	20.073
		Salt	6.982	1.450	0.935	1.765	1.835	0.950	0.035	3.185	8.540
		Water	2971	+1.338	−0.058	+3.077	−0.079	+1.318	+4.095	+1.841	+9.807

TABLE XVIII. PERIOD VI: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily rations	*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	75	Corn 1559.9	9.351	4.239	4.276	2.188	3.462	7.529	7.173	38.739
		Skim milk 3175.1	7.265	3.187	0.170	0.479	1.388	6.861	2.439	20.173
		Salt 6.117	1.318	0.787	1.117	1.613	0.441	0.012	2.789	4.560
		Water 3950	+0.768	+0.265	+2.989	+0.096	+1.633	+0.656	+1.945	+14.006
II	102	Corn 1914.5	11.477	5.203	5.248	2.685	4.249	9.240	8.863	47.544
		Skim milk 3896.8	9.030	3.186	0.277	0.482	2.261	8.297	2.725	29.674
		Salt 7.508	2.081	0.967	1.745	2.052	0.569	0.011	4.008	5.770
		Water 1100	+0.366	+1.050	+3.226	+0.151	+1.419	+0.932	+2.070	+12.100
III	91	Corn 1868.7	11.208	5.078	5.128	2.621	4.148	9.019	8.598	46.408
		Skim milk 3803.6	9.155	3.977	0.198	0.506	2.028	8.337	2.949	30.563
		Salt 7.328	1.817	0.684	1.440	1.976	0.464	0.010	3.645	4.824
		Water 3630	+0.231	+0.417	+3.485	+0.139	+1.656	+0.672	+1.999	+11.021
IV	71	Corn 1386.6	8.313	3.768	3.802	1.945	3.078	6.692	6.376	34.435
		Skim milk 2822.4	6.913	2.448	0.164	0.235	1.229	6.197	1.917	20.534
		Salt 5.438	1.099	0.727	1.217	1.577	0.387	0.008	2.928	3.931
		Water 3900	+0.301	+0.593	+2.421	+0.133	+1.462	+0.487	+1.531	+9.970
V	90	Corn 1711.3	10.259	4.650	4.692	2.400	3.799	8.260	7.869	42.499
		Skim milk 3483.3	7.914	2.838	0.123	0.397	.908	3.006	2.457	25.489
		Salt 6.711	1.781	0.609	1.357	1.888	0.545	0.019	3.425	5.276
		Water 880	+0.614	+1.203	+3.112	+0.115	+1.346	+5.285	+1.987	+11.734

TABLE XIX. PERIOD VII: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily rations	*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	83	Corn 1559.9	5.478	2.753	0.208	1.743	2.375	4.627	4.192	22.422
		Salt 6.117	2.820	2.862	0.119	0.298	1.237	4.268	1.726	14.357
		Water 5940	1.624	0.345	0.431	1.519	0.352	0.018	2.432	3.387
			+1.034	−0.454	−0.342	−0.074	+0.786	+0.341	+0.034	+4.678
II	110	Corn 1914.5	6.724	3.379	0.256	2.139	2.915	5.679	5.145	27.518
		Salt 7.508	2.717	2.401	0.179	0.300	1.481	5.055	1.543	15.750
		Water 4345	2.478	0.743	0.636	1.993	0.518	0.045	3.469	5.462
			+1.529	+0.235	−0.559	−0.154	+0.916	+0.579	+0.133	+6.306
III	99	Corn 1868.7	6.563	3.298	0.250	2.088	2.846	5.543	5.022	26.860
		Salt 7.328	3.007	3.241	0.139	0.316	1.586	4.987	1.801	16.561
		Water 6770	2.027	0.533	0.562	1.926	0.423	0.024	3.117	4.188
			+1.529	−0.476	−0.451	−0.154	+0.837	+0.532	+0.104	+6.111
IV	79	Corn 1386.6	4.870	2.447	0.185	1.549	2.112	4.113	3.726	19.931
		Salt 5.438	2.716	2.151	0.135	0.215	1.333	3.673	1.527	13.091
		Water 5900	1.362	0.555	0.469	1.440	0.309	0.025	2.215	3.005
			+0.792	−0.259	−0.419	−0.106	+0.470	+0.415	−0.016	+3.835
V	98	Corn 1711.3	6.010	3.020	0.229	1.912	2.606	5.076	4.599	24.598
		Salt 6.711	3.059	2.812	0.088	0.261	1.370	4.559	1.750	16.228
		Water 3710	1.895	0.491	0.504	1.759	0.417	0.041	2.779	3.852
			+1.056	−0.283	−0.363	−0.108	+0.819	+0.476	+0.070	+4.518

TABLE XX. PERIOD VIII: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
		Rice polish	1169.9	18.422	4.410	0.815	9.775	3.017	5.538	21.817	33.176
I	94	Wheat bran	390.0	16.202	1.148	0.116	0.527	1.202	3.789	00.937	16.708
		Salt	6.117	3.980	1.454	1.062	10.006	0.823	0.057	15.191	6.897
		Water	6470	−1.760	+1.808	−0.363	−0.758	+0.992	+1.692	+5.689	+9.571
		Rice polish	1039.9	16.376	3.920	0.724	8.689	2.682	4.923	19.401	29.489
IV	89	Wheat bran	346.7	14.053	1.238	0.132	0.373	0.812	3.880	00.754	14.012
		Salt	5.438	4.038	1.057	1.226	8.994	0.798	0.050	14.508	6.711
		Water	6835	−1.715	+1.625	−0.634	−0.678	+1.072	+0.993	+4.139	+8.766
		Rice polish	1120.6	17.645	4.224	0.780	9.363	2.880	5.305	20.905	31.776
V	109	Wheat bran	373.5	14.930	1.343	0.083	0.409	0.993	3.457	00.898	16.854
		Salt	5.854	4.628	0.711	1.195	9.740	0.816	0.066	15.070	6.127
		Water	5570	−1.913	+2.170	−0.498	−0.786	+1.061	+1.782	+4.937	+8.795

TABLE XXI. Daily Rations and Mineral Balances per Period—Average for Five Pigs—Grams

Period No.	Approximate live weight Kg.	Rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
II	63	Corn	1367.2	10.187	4.351	0.748	2.171	3.227	4.753	5.402	37.352
		Soybeans	271.4	4.789	1.253	0.092	0.222	1.561	3.760	1.209	18.679
		Salt	6.387	2.569	0.524	0.900	1.902	0.622	0.027	3.524	6.957
		Water	3461	+2.828	+2.573	−0.243	+0.046	+1.044	+0.966	+0.669	+11.717
III	64	Corn	1590.4	9.168	4.101	1.380	3.363	3.759	5.739	6.581	41.362
		Linseed oil meal	318.1	4.775	2.192	0.109	0.510	1.607	4.630	1.152	22.318
		Salt	7.485	3.101	0.746	0.927	2.946	0.805	0.042	4.923	7.678
		Water	5247	+1.292	+1.163	+0.344	−0.093	+1.346	+1.067	+0.507	+11.361
IV	71	Corn	1110.7	12.471	4.605	0.963	4.454	3.664	5.456	10.336	41.286
		Wheat middlings	837.9	6.048	2.173	0.182	0.528	1.698	5.019	3.754	20.808
		Salt	7.642	4.528	1.027	0.698	3.849	0.898	0.138	5.524	7.573
		Water	5074	+1.895	+1.405	+0.083	+0.076	+1.068	+0.299	+1.058	+12.909
V	78	Corn	1705.3	6.916	6.090	5.233	2.151	3.631	9.601	7.344	40.420
		Meat meal	170.5	4.167	5.310	0.211	0.341	1.163	8.725	2.125	22.671
		Salt	7.356	1.572	1.061	1.740	1.911	1.024	0.035	3.504	9.741
		Water	4768	+1.178	−0.281	+3.282	+0.101	+1.444	+0.841	+1.714	+8.007
VI	86	Corn	1688.2	10.121	4.588	4.628	2.368	3.747	8.148	7.763	41.926
		Skim milk	3436.2	8.055	3.127	0.186	0.420	1.763	6.540	2.497	25.287
		Salt	6.620	1.609	0.755	1.375	1.821	0.480	0.012	3.359	4.872
		Water	2692	+0.456	+0.706	+3.047	+0.127	+1.503	+1.596	+1.906	+11.766
VII	94	Corn	1688.2	5.929	2.979	0.226	1.886	2.571	5.008	4.537	24.266
		Salt	6.620	2.864	2.693	0.132	0.278	1.401	4.508	1.669	15.197
		Water	5738	1.877	0.533	0.520	1.727	0.404	0.031	2.802	3.979
				+1.188	−0.247	−0.427	−0.119	+0.766	+0.469	+0.065	+5.090
VIII	97	Rice polish	1110.1	17.481	4.185	0.773	9.276	2.863	5.255	20.708	31.480
		Wheat bran	370.1	15.062	1.243	0.110	0.436	1.002	3.709	0.868	15.868
		Salt	5.808	4.215	1.074	1.161	9.580	0.812	0.058	14.923	6.578
		Water	6292	−1.796	+1.868	−0.498	−0.741	+1.038	+1.489	+4.922	+9.044

TABLE XXII. Average Daily Intake of Mineral Elements and Partition of Outgo Between Urine and Feces—Urine and Feces Together Equal 100 Percent. Intake (upper figure) in Grams; Urine (middle figure) and Feces (lower figure) in Percent of Outgo.

Periods	Rations	*Potassium* Intake Urine Feces	*Sodium* Intake Urine Feces	*Calcium* Intake Urine Feces	*Magnesium* Intake Urine Feces	*Sulphur* Intake Urine Feces	*Chlorine* Intake Urine Feces	*Phosphorus* Intake Urine Feces
II	Corn; soy beans	10.187 66.2 33.8	4.021 70.7 29.3	0.748 9.3 90.7	2.171 10.4 89.6	3.227 71.6 28.4	4.763 99.4 0.6	5.402 25.5 74.5
III	Corn; linseed oil meal	9.168 61.5 38.5	4.101 87.3 12.7	1.380 10.4 89.6	3.363 14.6 85.4	3.759 66.2 33.8	5.739 99.1 0.9	6.581 18.8 81.2
IV	Corn; wheat middlings	12.471 57.4 42.6	4.605 67.5 32.5	0.963 20.7 79.3	4.454 12.0 88.0	3.664 65.4 34.6	5.456 97.4 2.6	10.335 40.5 59.5
V	Corn; meat meal	6.916 72.9 27.1	6.090 83.5 16.5	5.233 10.7 89.3	2.151 15.2 84.8	3.631 53.9 46.1	9.601 99.5 0.5	7.344 37.9 62.1
VI	Corn; milk	10.121 83.5 16.5	4.588 80.4 19.6	4.628 11.8 88.2	2.368 18.6 81.4	3.747 78.3 21.7	8.148 99.9 0.1	7.763 42.6 57.4
VII	Corn	5.929 60.9 39.1	2.979 83.5 16.5	0.226 20.3 79.7	1.866 13.9 86.1	2.571 77.8 22.2	5.008 99.3 0.7	4.537 37.7 62.3
VIII	Rice polish; wheat bran	17.481 78.1 21.9	4.185 53.8 46.2	0.773 8.7 91.3	9.276 4.35 95.65	2.863 55.1 44.9	5.255 98.4 1.6	20.708 5.5 94.5

TABLE XXIII: Proportionate Elimination and Retention of Mineral Elements. Averages from Five Individuals—Intake (upper figure) in Grams; Urine (second figure), Feces (third figure), and Retention (lower figure) in Percent of Intake.

Periods	Rations	*Potassium* Intake Urine Feces Retention	*Sodium* Intake Urine Feces Retention	*Calcium* Intake Urine Feces Retention	*Magnesium* Intake Urine Feces Retention	*Sulphur* Intake Urine Feces Retention	*Chlorine* Intake Urine Feces Retention	*Phosphorus* Intake Urine Feces Retention
II	Corn; soy beans	10.187 48.0 24.5 +27.5	4.351 28.8 12.0 +59.1	0.748 12.2 120.3 —32.5	2.171 10.2 87.9 +1.9	3.227 48.4 19.3 +32.3	4.753 79.1 0.6 +20.3	5.402 22.4 65.2 +12.4
III	Corn; linseed oil meal	9.168 52.0 32.5 +14.4	4.101 53.4 18.2 +28.3	1.380 7.9 67.2 +24.9	3.363 15.0 87.7 —2.8	3.759 42.7 21.4 +35.8	5.739 80.7 0.7 +18.6	6.581 17.4 74.9 +7.7
IV	Corn; wheat middlings	12.471 48.6 36.1 +15.3	4.605 47.2 22.3 +30.5	0.963 18.9 72.5 +8.6	4.454 11.8 86.4 +1.8	3.664 46.3 24.5 +29.1	5.456 91.9 3.5 +5.5	10.335 36.4 53.4 +10.3
V	Corn; meat meal	6.916 60.3 22.4 +17.4	6.090 87.2 17.4 —46.1	5.233 4.0 33.2 +62.7	2.151 15.9 88.8 —4.7	3.631 32.0 28.2 +29.8	9.601 90.8 0.4 +8.7	7.344 29.0 47.5 +23.5
VI	Corn; skim milk	10.121 79.7 15.7 +4.6	4.588 68.1 16.4 +15.4	4.628 4.0 29.7 +65.8	2.368 17.6 77.1 +5.4	3.747 47.1 12.8 +40.1	8.148 80.2 0.1 +19.5	7.768 32.1 43.2 +24.6
VII	Corn	5.929 48.9 31.4 +19.8	2.979 90.4 17.9 —8.3	0.226 88.4 230.0 —18.9	1.886 14.8 91.5 —6.3	2.571 54.5 15.7 +29.7	5.008 90.0 0.6 +9.4	4.537 37.2 61.5 +1.3
VIII	Rice polish; wheat bran	17.481 86.1 24.2 —10.3	4.185 29.7 25.7 +44.6	0.778 14.2 150.1 —64.4	9.276 4.7 103.3 —8.0	2.868 35.0 28.3 +36.2	5.265 70.6 0.1 +28.3	20.708 4.2 72.2 +23.7

THE HAMILTON COUNTY EXPERIMENT FARM

SECOND ANNUAL REPORT, FOR THE YEAR 1913

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., MAY, 1914

BULLETIN 272

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

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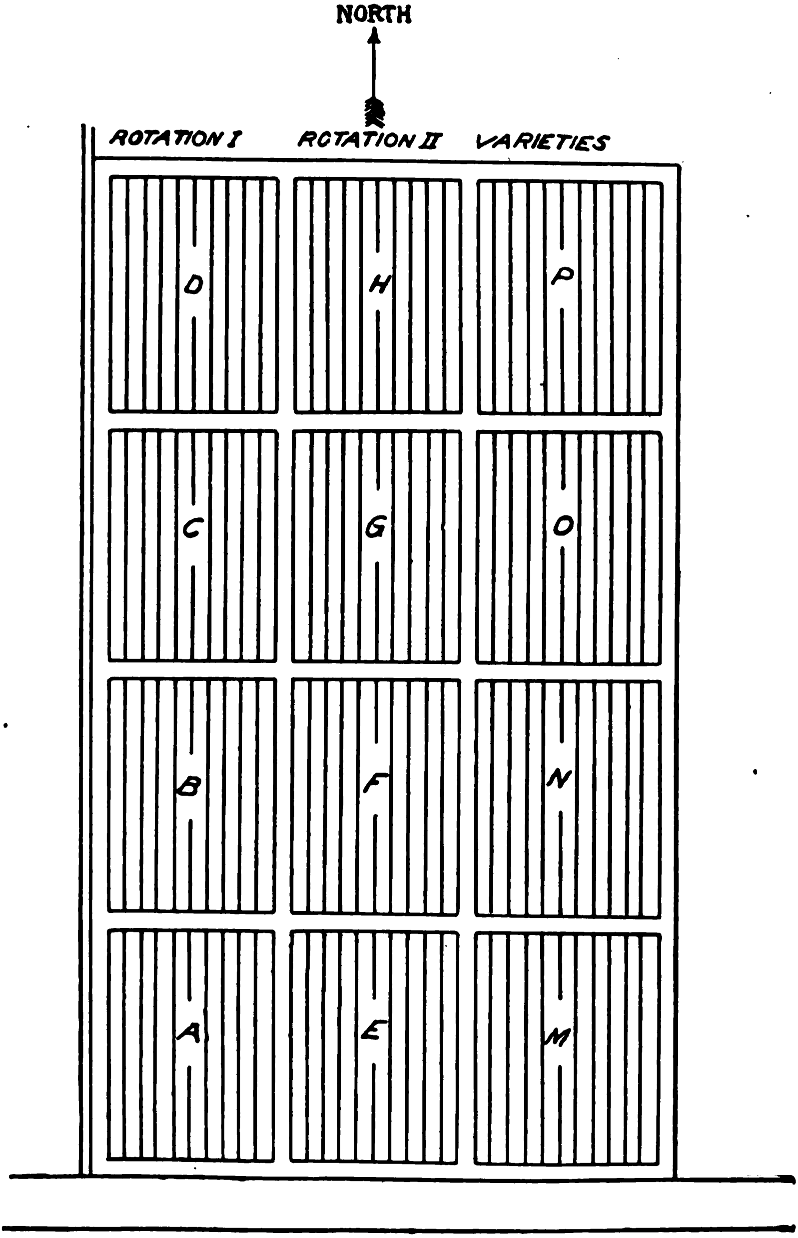

Diagram: Arrangement of plots in cereal rotations
Hamilton County Experiment Farm

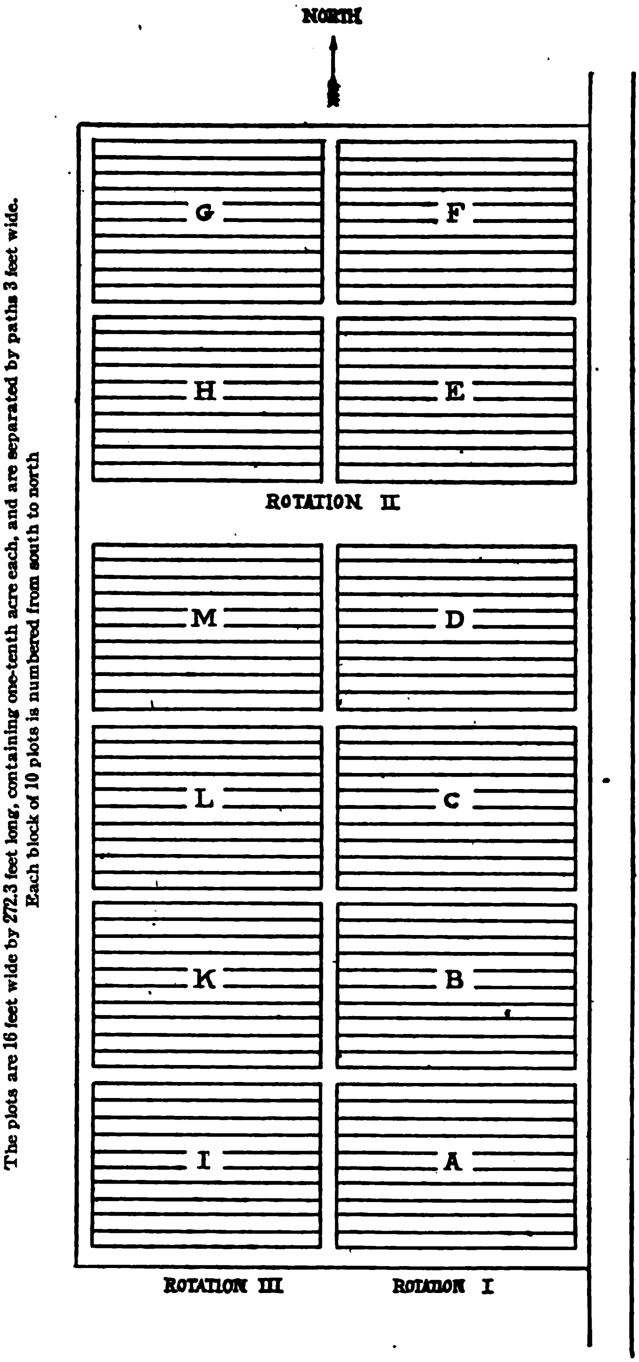

Diagram I. Arrangement of plots in cereal rotations, Miami County Experiment Farm

TABLE I: Plan of fertilizing in cereal rotations, Miami county experiment farm.

Pounds of fertilizing materials per acre for each crop

Plot No.	Acid phosphate	Muriate potash	Nitrate soda	Powdered limestone	Acid phosphate	Muriate potash	Nitrate soda	Acid phosphate	Muriate potash	Nitrate soda
Rotation I: Corn, oats, wheat, clover										
	On Corn				On Oats			On Wheat		
1	..	..	..	......	...	..	..	...	..	..
2	200	..	..	......	100	..	..	200	..	..
3	200	50	..	......	100	20	..	200	20	..
4	...	..	..	......	...	..	..	...	..	..
5	200	50	50	......	100	20	30	200	20	80
6	200	50	50	4,000*	100	20	30	200	20	80
7	...	..	..	......	...	..	..	...	..	..
8	Manure, 8 tons		..	......	...	..	..	200	50	50
9	Manure, 8 tons, phosphated			......	...	..	..	200	50	50
10	...	..	..	......	...	..	..	...	..	..
Rotation II: Corn, soybeans, wheat, clover										
	On Corn				On Soybeans			On Wheat		
1	...	..	..	..	...	..	..	...	..	..
2	200	..	..	..	100	..	..	200	..	..
3	200	50	..	..	100	20	..	200	20	..
4	...	..	..	..	...	..	..	...	..	..
5	200	50	50	..	100	20	30	200	20	80
6	130	50	20	..	70	20	10	160	20	20
7	...	..	..	..	...	..	..	...	..	..
8	160	20	20	..	100	..	..	170	..	30
9	160	20	20	†	100	..	..	170	..	30
10	...	..	..	..	...	..	..	...	..	..
Rotation III: Corn, corn, oats, clover										
	On Corn 1st				On Corn 2nd			On Oats		
1	...	..	..	......	...	..	..	...	..	..
2	200	..	..	......	200	..	..	100	..	..
3	200	50	..	......	200	20	..	100	20	..
4	...	..	..	......	...	..	..	...	..	..
5	200	50	50	......	200	20	80	100	20	30
6	200	50	50	4,000*	200	20	80	100	20	30
7	...	..	..	......	...	..	..	...	..	..
8	Manure, 8 tons		..	......	200	50	50	...	..	..
9	Manure, 8 tons, phosphated*			......	200	50	50	...	..	..
10	...	..	..	......	...	..	..	...	..	..

*2,000 pounds in 1912. †Catch crop to follow corn.

Cropping in 1913:

Rotation I	Rotation II	Rotation III
Block D—Corn	Block E—Corn	Block J—Corn 1st
" C—Oats	" F—Soybeans	" M—Corn 2nd
" B—Wheat	" G—Wheat	" L—Oats

TABLE II: Plan of fertilizing in cereal rotations, Miami county experiment farm. Total fertilizing materials for one rotation; constituents and percentage composition

Plot No.	Total fertilizing materials for one rotation				Fertilizing constituents contained			Percentage composition		
	Nitrate soda	Acid phosphate	Muriate potash	Total pounds	Ammonia	Phosphoric acid	Potash	Ammonia	Phosphoric acid	Potash
Rotation I: Corn, oats, wheat, clover										
2	...	500	..	500	..	70	..	.	14	.
3	...	500	90	590	..	70	45	.	12	7
5	160	500	90	750	30	70	45	4	9.5	6
6	160	500	90	750	30	70	45	4	9.5	6
8	...	300	..	300	9.5	28	25	3	9	8
9	...	300	..	300	9.5	28	25	3	9	8
Rotation II: Corn, soybeans, wheat, clover										
2	...	500	..	500	..	70	..	.	14	.
3	...	500	90	590	..	70	45	.	12	7
5	160	500	90	750	30	70	45	4	9.5	6
6	50	360	90	500	9.5	50	45	2	10	9
8	50	430	20	500	9.5	60	10	2	12	2
9	50	430	20	500	9.5	60	10	2	12	2
Rotation III: Corn, corn, oats, clover										
2	...	500	..	500	..	70	..	.	14	.
3	...	500	90	590	..	70	45	.	12	7
5	160	500	90	750	30	70	45	4	9.5	6
6	160	500	90	750	30	70	45	4	9.5	6
8	50	200	50	300	9.5	28	25	3	9	8
9	50	200	50	300	9.5	28	25	3	9	8

In Rotations I and III the only difference in treatment between Plots 5 and 6 is in the lime applied on Plot 6 to the corn crop.

In Rotations II and III the variation between Plots 8 and 9 is in the treatment of the manure on the corn crop.

TABLE III, Part 1: Fertilizers and manure on CORN. Miami County Experiment Farm.

Plot No.	Treatment per acre	1913 Yield per acre Grain Bus.	1913 Yield per acre Stover Lbs.	1913 Increase per acre Grain Bus.	1913 Increase per acre Stover Lbs.	3-year average Yield per acre Grain Bus.	3-year average Yield per acre Stover Lbs.	3-year average Increase per acre Grain Bus.	3-year average Increase per acre Stover Lbs.	Plot No.
	Rotation I (Corn-oats-wheat-clover) Block D									
1	None	25.29	1,700	....	...	41.62	2,330	.....	...	1
2	Acid phosphate, 200 lbs	41.43	1,600	11.38	*100	51.19	2,433	9.48	167	2
3	Acid phosphate, 200 lbs.; muriate potash, 50 lbs	44.00	2,100	9.19	400	54.02	2,740	12.23	537	3
4	None	39.57	1,700	....	....	41.88	2,140	.....	...	4
5	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	44.86	1,650	1.96	*217	50.98	2,427	8.90	249	5
6	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs; powdered limestone, 2,000 lbs.	49.86	2,350	3.62	317	54.12	2,657	11.84	441	6
7	None	49.57	2,200	....	....	42.48	2,253	.....	...	7
8	Untreated manure, 8 tons	64.43	2,450	6.50	*17	56.67	2,430	13.63	233	8
9	Phosphated manure, 8 tons	74.00	3,000	7.72	267	62.48	2,917	18.88	777	9
10	None	74.64	3,000	....	....	44.16	2,083	.....	...	10
	Average unfertilized yield	47.27	2,150	...	....	42.53	2,202	.....	...	
	Rotation II (Corn-soybeans-wheat-clover) Block E									
1	None	68.71	3,200	....	...	61.00	2,717	....	...	1
2	Acid phosphate, 200 lbs.	73.57	3,200	8.19	133	66.19	2,780	7.37	174	2
3	Acid phosphate, 200 lbs.; muriate potash, 50 lbs	72.29	3,600	10.25	667	67.57	3,050	10.93	556	3
4	None	58.71	2,800	....	...	54.47	2,383	....	...	4
5	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	58.86	3,150	3.48	433	56.81	2,733	4.16	368	5
6	Acid phosphate, 130 lbs.; muriate potash, 50 lbs.; nitrate soda, 20 lbs	53.29	2,800	1.25	167	55.10	2,580	4.28	232	6
7	None	48.71	2,550	....	...	49.00	2,330	....	...	7
8	Acid phosphate, 160 lbs.; muriate potash, 20 lbs.; nitrate soda, 20 lbs.**	55.29	2,800	9.01	233	56.95	2,580	9.68	323	8
9	Acid phosphate, 160 lbs.; muriate potash, 20 lbs.; nitrate soda, 20 lbs.**	50.43	2,560	6.57	377	51.19	2,660	5.65	477	9
10	None	41.43	2,000	....	...	43.81	2,110	....	...	10
	Average unfertilized yield	54.39	2,637	....	...	52.07	2,385	....	...	

*Decrease. **Plots 8 and 9, Rotation II, are treated alike, except that catch crops follow corn on Plot 9.

TABLE III, Part 2: Fertilizers and manure on CORN. Miami County Experiment Farm.

Plot No.	Treatment per acre	1913 Yield per acre Grain Bus.	1913 Yield per acre Stover Lbs.	1913 Increase per acre Grain Bus.	1913 Increase per acre Stover Lbs.	3-year average Yield per acre Grain Bus.	3-year average Yield per acre Stover Lbs.	3-year average Increase per acre Grain Bus.	3-year average Increase per acre Stover Lbs.	Plot No.
	Rotation III (Corn-corn-wheat-clover) Corn first crop: Block I									
1	None	36.64	1,650	....	...	31.21	1,767	.....	...	1
2	Acid phosphate, 200 lbs.	44.71	2,000	4.83	200	44.71	2,083	10.69	239	2
3	Acid phosphate, 200 lbs.; muriate potash, 50 lbs	52.71	2,150	9.58	200	52.09	2,433	15.26	511	3
4	None	46.37	2,100	....	...	39.65	2,000	.....	...	4
5	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	55.50	2,750	9.37	683	52.41	2,483	12.73	420	5
6	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs.; powdered limestone, 2,000 lbs.	53.93	2,200	8.05	167	53.74	2,350	14.03	223	6
7	None	45.64	2,000	....	...	39.74	2,190	.....	...	7
8	Untreated manure, 8 tons	61.93	2,700	8.10	417	61.74	2,847	17.60	553	8
9	Phosphated manure, 8 tons	72.71	2,800	10.69	233	62.85	2,850	14.42	453	9
10	None	70.21	2 850	....	...	52.93	2 500	.... .	...	10
	Average unfertilized yield	49.71	2 150	....	...	40.88	2 114	.....	...	
	Rotation III (Corn-corn-wheat-clover) Corn second crop: Block M									
1	None	19.14	1,450	.....	...	25.52	1,583	.....	...	1
2	Acid phosphate, 200 lbs.	32.64	2,150	12.00	683	43.78	2,277	13.95	569	2
3	Acid phosphate, 200 lbs; muriate potash, 20 lbs.	31.57	1,950	9.43	467	47.67	2,463	13.52	631	3
4	None	23.64	1,500	.....	...	38.45	1,957	.....	.	4
5	Acid phosphate, 200 lbs.; muriate potash, 20 lbs.; nitrate soda; 80 lbs	29.57	1,950	5.43	317	48.00	2,517	10.53	533	5
6	Acid phosphate, 200 lbs.; muriate potash, 20 lbs.; nitrate soda, 80 lbs	31.36	2,450	6.72	683	48.83	2,703	12.34	693	6
7	None	25.14	1,900	.....	...	35.52	2,037	.....	...	7
8	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	32.00	2,700	2.26	483	50.76	2,863	15.75	746	8
9	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	35.80	3,000	1.47	467	50.70	2,907	16.20	708	9
10	None	38.93	2 850	.....	...	33.98	2,280	.....	...	10
	Average unfertilized yield	26.71	1 925	.....	...	33.37	1 965	.....	...	

TABLE IV: Fertilizers and manure on OATS. Miami County Experiment Farm.

Plot No.	Treatment per acre	1913 Yield per acre Grain Bus.	1913 Yield per acre Stover Lbs.	1913 Increase per acre Grain Bus.	1913 Increase per acre Stover Lbs.	2-year average Yield per acre Grain Bus.	2-year average Yield per acre Stover Lbs.	2-year average Increase per acre Grain Bus.	2-year average Increase per acre Stover Lbs.	Plot No.
	Rotation I (Corn-oats-wheat-clover) Block C									
1	None	47.66	3,200	....	...	51.01	3,145	....	...	1
2	Acid phosphate, 100 lbs.	48.75	3,040	2.81	202	53.94	3,248	2.02	338	2
3	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.	52.50	2,620	8.28	143	60.62	3,047	7.79	371	3
4	None	42.50	2,115	....	...	53.75	2,442	....	...	4
5	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.; nitrate soda, 30 lbs	53.55	2,217	11.62	192	60.68	2,448	8.17	157	5
6	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.; nitrate soda, 30 lbs	52.50	2,720	11.15	785	61.17	2,642	9.92	503	6
7	None	40.78	1,845	....	...	50.00	1,987	....	...	7
8	(Manured on corn)	44.84	2,115	5.93	360	44.84*	2,115*	5.93*	360*	8
9	(Manured on corn)	45.94	2,230	8.91	565	45.94*	2,230*	8.91*	565*	9
10	None	35.16	1,575	....	...	35.16*	1,575*	....	...	10
	Average unfertilized yield	41.53	2,184	....	..	47.48	2,287	....	...	
	Rotation III (Corn-corn-oats-clover) Block L									
1	None	34.37	1,800	.....	...	44.68	2,370	....	...	1
2	Acid phosphate, 100 lbs.	52.35	2,525	12.56	357	51.49	2,565	2.54	**39	2
3	Acid phosphate, 100 lbs.; muriate potash, 20 lbs	58.28	3,186	13.08	648	61.88	3,405	8.64	456	3
4	None	50.62	2,905	.....	...	67.49	3,072	....	...	4
5	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.; nitrate soda, 30 lbs	58.44	3,080	10.06	370	63.05	3,120	7.92	276	5
6	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.; nitrate soda, 30 lbs	58.75	3,145	12.60	630	62.03	3,097	9.27	482	6
7	None	43.91	2,320	.....	...	50.39	2,387	....	...	7
8	(Manured on corn)	50.62	2,730	7.86	532	50.62*	2,730*	7.86*	532*	8
9	(Manured on corn)	53.12	2,875	11.50	798	53.11*	2,875*	11.50*	798*	9
10	None	40.47	1,955	.....	...	40.47	1,955*	....	...	10
	Average unfertilized yield	42.35	2,245	.....	...	48.26	2,446	....	...	

*One year. **Decrease.

TABLE V: Fertilizers on SOYBEANS. Miami County Experiment Farm, 1912 and 1913. Rotation II, Block F

Plot No.	Treatment per acre	Yield per acre 1912 Bus.	Yield per acre 1913 Bus.	Yield per acre Av. Bus.	Increase per acre 1912 Bus.	Increase per acre 1913 Bus.	Increase per acre Av. Bus.	Plot No.
1	None	20.00	18.33	19.16	....	....	....	1
2	Acid phosphate, 100 lbs.	21.00	18.08	19.54	0.22	0.80	0.51	2
3	Acid phosphate, 100 lbs.; Muriate potash, 20 lbs.	23.67	17.25	20.46	2.12	1.03	1.57	3
4	None	22.33	15.17	18.75	....	....	....	4
5	Acid phosphate, 100 lbs.; Muriate potash, 20 lbs.; Nitrate soda, 30 lbs.	26.00	14.75	20.37	1.95	*0.06	0.94	5
6	Acid phosphate, 70 lbs.; Muriate potash, 20 lbs.; Nitrate soda, 10 lbs.	23.50	12.83	18.16	*2.28	*1.61	*1.94	6
7	None	27.50	14.08	20.79	....	....	....	7
8	Acid phosphate, 100 lbs.	29.17	13.58	21.37	2.51	*0.81	0.85	8
9	Acid phosphate, 100 lbs.	27.17	13.83	20.50	1.33	*0.86	0.23	9
10	None	25.00	15.00	20.00	....	....	....	10
	Average unfertilized yield	23.71	15.65	19.68	....	....	....	

*Decrease.

TABLE VI: Fertilizers and manure on WHEAT. Miami County Experiment Farm, 1913

Plot No.	Treatment	Yield per acre Grain Bus.	Yield per acre Straw Lbs.	Increase per acre Grain Bus.	Increase per acre Straw Lbs.
	Rotation I (Corn-oats-wheat-clover) Block B				
1	None	29.17	3,625	....	....
2	Acid phosphate, 200 lbs.	33.00	3,920	4.05	440
3	Acid phosphate, 200 lbs.; muriate potash, 20 lbs.	35.67	4,210	6.95	875
4	None	28.50	3,190	....	....
5	Acid phos., 200 lbs.; mur. potash, 20 lbs.; nit. soda, 80 lbs.	30.00	3,550	6.44	877
6	Acid phos., 200 lbs.; mur. potash, 20 lbs.; nit. soda, 80 lbs.[1]	29.33	3,440	10.72	1,283
7	None	13.67	1,640	....	....
8	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs.[2]	28.58	3,335	9.02	1,035
9	Acid phos., 200 lbs.; mur. potash, 50 lbs., nit. soda, 50 lbs.[3]	30.58	3,765	5.14	805
10	None	31.33	3,620	....	....
	Average unfertilized yield	25.67	3,019	....	....
	Rotation II (Corn-soybeans-wheat-clover) Block G				
1	None	32.50	3,400	....	....
2	Acid phosphate, 200 lbs.	34.17	4,130	1.64	515
3	Acid phosphate, 200 lbs.; muriate potash, 20 lbs.	38.58	5,035	6.03	1,205
4	None	32.58	4,045	....	....
5	Acid phos., 200 lbs.; mur. potash, 20 lbs.; nit. soda, 80 lbs.	43.50	5,800	12.03	1,822
6	Acid phos., 160 lbs.; mur. potash, 20 lbs.; nit. soda, 20 lbs.	42.50	5,550	12.14	1,638
7	None	29.25	3,845	....	....
8	Acid phos., 170 lbs.; nitrate soda, 30 lbs.	38.08	5,115	10.47	1,588
9	Acid phos., 170 lbs.; nitrate soda, 30 lbs[4]	35.21	4,427	9.24	1,219
10	None	24.33	2,890	....	....
	Average unfertilized yield	29.67	3,545	....	....

[1]Fertilizers and limestone on corn. [2]Untreated manure on corn. [3]Phosphated manure on corn. [4]Catch crop to follow corn.

TABLE VII: Fertilizers and manure on cereal crops grown in rotation, Miami County Experiment Farm: Average value of increase, cost of fertilizers and net gain per acre.

Plot No.	Treatment per acre Total fertilizers and manure for one 4-year rotation	Average increase per acre: Corn Grain Bus.	Corn Stover Lbs.	Oats or soybeans Grain Bus.	Oats or soybeans Straw Lbs.	Wheat Grain Bus.	Wheat Straw Lbs.	Total value of increase	Total cost of fertilizer	Net gain	Plot No.
	Rotation I (Corn-oats-wheat-clover)										
1	None	....	...	....	...	....	...	.....	.....	....	1
2	Acid phosphate, 500 lbs.	9.48	167	2.02	338	4.05	440	$ 9.07	$3.80	$5.27	2
3	Acid phosphate, 500 lbs.; muriate potash, 90 lbs	12.23	537	7.79	371	6.95	875	14.84	5.88	8.96	3
4	None	....	...	....	...	....	...	.....	.....	....	4
5	Acid phosphate, 500 lbs.; muriate potash, 90 lbs.; nitrate soda, 160 lbs	8.90	249	8.17	157	6.44	877	12.57	10.88	1.69	5
6	Acid phos., 500 lbs.; mur. potash, 90 lbs.; nit. soda, 160 lbs.; ground limestone, 2 tons	11.84	441	9.92	503	10.72	1,283	18.73	14.88	3.85	6
7	None	....	...	....	...	....	....	.....	.....	....	7
8	Acid phosphate, 200 lbs.; untreated manure, 8 tons	13.63	233	5.93	360	9.02	1,035	16.19	2.28	....	8
9	Acid phosphate, 200 lbs.; phosphated manure, 8 tons	18.88	777	8.91	565	5.14	805	16.87	4.71	....	9
10	None	.....	...	....	...	....	...	.....	.....	..	10
	Rotation II (Corn-soybeans-wheat-clover)										
1	None	....	...	....	....	....	...	.....	....	....	1
2	Acid phosphate, 500 lbs.	7.37	171	0.51	....	1.64	515	$ 6.05	$3.80	$2.25	2
3	Acid phosphate, 500 lbs.; muriate potash, 90 lbs	10.93	556	1.57	....	6.03	1,205	14.37	6.07	8.30	3
4	None	....	...	....	....	....	...	.....	....	....	4
5	Acid phosphate, 500 lbs.; muriate potash, 90 lbs.; nitrate soda, 160 lbs.	4.16	368	0.94	....	12.03	1,822	15.54	10.87	4.67	5
6	Acid phosphate, 360 lbs.; muriate potash, 90 lbs.; nitrate soda, 50 lbs	4.28	232	*1.94	....	12.14	1,638	9.53	6.31	3.22	6
7	None	....	...	....	....	....	.....	.....	....	....	7
8	Acid phosphate, 430 lbs.; muriate potash, 20 lbs.; nitrate soda, 50 lbs	9.68	323	0.85	....	10.47	1,588	16.02	5.08	10.94	8
9	Acid phos., 430 lbs.; muriate potash, 20 lbs.; nitrate soda, 50 lbs. Catch crop**	5.65	477	0.23	....	9.24	1,219	12.05	10.08	1.97	9
10	None	....	...	....	....	....	.....	....	....	....	10

*Decrease. **A catch crop of 1 bu. rye and 40 lbs. hairy vetch per acre, estimated cost, including labor of seeding, $5.00.

TABLE VII—Continued

Plot No.	Treatment per acre Total fertilizers and manure for one 4-year rotation	Average increase per acre						Total value of increase	Cost of fertilizer	Net gain	Plot No.
		Corn, 1st year		Corn, 2nd year		Oats					
		Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Straw Lbs.				
	Rotation III (Corn-corn-oats-clover)										
1	None	.....	...	.....	...	....	...	.....	.....	.....	1
2	Acid phosphate, 500 lbs.	10.69	239	13.96	569	2.54	*39	$11.79	$3.80	$7.99	2
3	Acid phosphate, 500 lbs.; muriate potash, 90 lbs	15.26	511	13.52	631	8.64	456	16.27	5.08	11.19	3
4	None	.....	...	.....	...	....	...	.....	.....	.....	4
5	Acid phosphate, 500 lbs.; muriate potash, 90 lbs.; nitrate soda, 160 lbs.	12.73	420	10.53	533	7.92	276	13.38	10.88	2.50	5
6	Acid phos., 500 lbs.; muriate potash, 90 lbs.; nitrate soda, 160 lbs.; limestone, 2 tons.	14.03	223	12.34	693	9.27	482	15.18	14.88	.30	6
7	None	.....	...	.....	...	....	...	.....	.....	.....	7
8	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs.; manure, 8 tons.	17.60	553	15.75	746	7.86	532	18.18	4.28	.....	8
9	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs.; phosphated manure, 8 tons	14.42	453	16.20	708	11.50	798	18.24	6.66	.....	9
10	None	.....	...	.....	...	....	...	.....	.....	.....	10

*Decrease.

In calculating the increase in these experiments it is assumed that the variations in natural productiveness between different plots are progressive; that is, that if Plots 1 and 4, untreated, yield 30 and 33 bushels respectively, the probability is that if Plots 2 and 3 had been left without treatment their yields would have been 31 and 32 bushels, respectively. Of course this assumption is not always correct, but experience has shown that in general the results arrived at in this way are more trustworthy than would be found by taking the general average of all the unfertilized plots as a basis of comparison.

The difference between the two methods of computation is illustrated by the outcome of the corn crop of 1913. In Block D, Rotation I, for example, the unfertilized yields range from 25.29 bushels on Plot 1 to 74.64 bushels on Plot 10. At first glance it would seem that such an irregularity in yield must completely nullify the experiment, and it certainly would, had there been left only one or two untreated plots, or were we to take the simple average of all the unfertilized plots, or of any two of them, as a guide. This point is brought out by Diagram II, which shows that the variation in unfertilized yield has been comparatively uniform, and that the method of calculation adopted and as represented by the lines A B gives results which may be accepted as at least much nearer the truth than would have been obtained by taking as a basis the general average, represented by the lines C D.

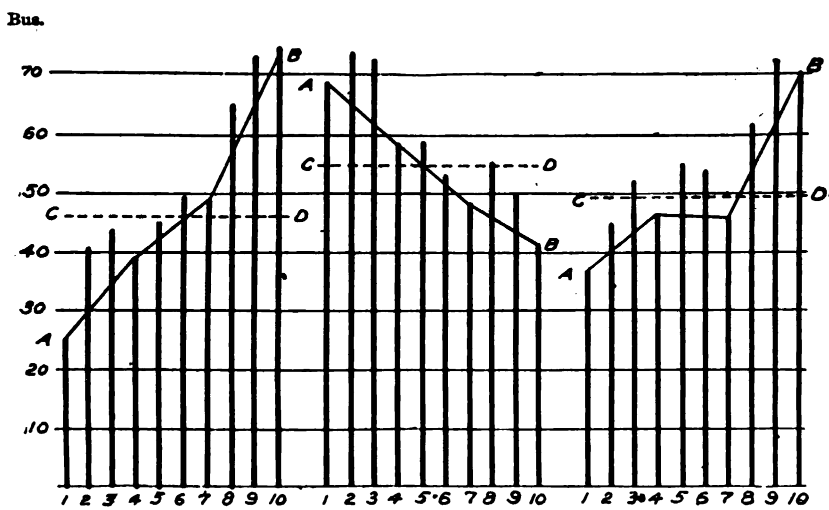

Diagram II: Illustrating method of computing increase.

One of the reasons for the variations in yield shown in this experiment is that the land itself is not as uniform as is desirable for this work, part of it being yellow clay and part black land. It was found so difficult to get enough of either kind of land in one body for this test that it was decided to depend upon the check plots for determining the variation in yield. In this connection it is interesting to compare the two blocks, D and E, which stand on opposite sides of a broad strip of low, black land, which was omitted from the test because of its character. It will be observed that the yield increases rapidly on both sides as this strip of land is approached. Miami County suffered from drought in 1913, and this low land was in better condition as to moisture than the higher land.

Past experience justifies the expectation that as this work progresses under uniform treatment the difference in yield due to superficial soil variations will be modified, and that the effect of the treatment will become more definite.

THE OUTCOME OF THE EXPERIMENTS

It is too early as yet to attempt to draw any but the most general conclusions from these experiments. The first rotation of four years is not yet completed, the clover crop being yet to come, and experience has shown that we may not only expect an increase in the hay crop from the fertilizers and manures which have been applied to the three preceding cereal crops, but that a considerable part of the effect of the treatment will be realized during the next rotation. For example, the average value of the increase of crops from a dressing of acid phosphate on crops grown in a 5-year rotation of corn, oats, wheat, clover and timothy, was $8.50 per acre for the first 5 years at Wooster and $14.12 at Strongsville, and for the second 5 years it was $17.37 at Wooster and $21.60 at Strongsville.

It seems safe to assume, however, that acid phosphate is producing a very profitable increase on all the crops in the three cereal rotations in progress at this farm, and that both total and net gains are increased where the acid phosphate is reenforced by muriate of potash, thus indicating that this land is deficient in both phosphorus and potassium.

When nitrate of soda has been added to the combination of acid phosphate and muriate of potash the calculated increase in the corn crop is found to be smaller in most cases than from those applications in which the nitrate was omitted. In the case of the oats and wheat crops, however, there is usually an increased yield following the addition of nitrate of soda to the fertilizer, although in no case

has the total increase in the three crops thus far grown in this rotation been sufficient to offset the additional cost of the fertilizer when nitrate of soda has been added, as shown by the general summary given in Table III. It must be remembered, however, that this summary is incomplete, as the clover crop is yet to be heard from.

In the case of the barnyard manure, as used in rotations I and III, an increase is found equivalent to about $14 for 8 tons of untreated manure at this stage of the work, with the probability that the clover crop will bring up the net gain to at least $2.00 per ton of manure. Thus far neither the reenforcement of the manure with acid phosphate nor the supplementing it with a complete fertilizer has produced sufficient increase to justify the additional cost, but it is quite too early to attempt to draw final conclusions. Referring again to the experiments at Wooster and Strongsville, we find that the increase from 8 tons of yard manure during three successive 5-year periods amounted to $12.02, $21.28, and $35.36 at Wooster, and to $12.56, $12.62 and $21.22 at Strongsville, the slower rate of increase at Strongsville being due to a less responsive soil and to an inferior quality of manure.

CONCLUSIONS

At the present stage of this work it seems evident that the soil of Miami County will respond very profitably to fertilizers containing phosphorus and potassium, but that nitrogen should be obtained by the careful saving of barnyard manure and the growing of clover, alfalfa and similar crops, rather than by its purchase in commercial fertilizers. For nitrate of soda is not only the most effective but the cheapest source of fertilizer nitrogen, and if it fails to produce a profit the farmer may be sure that the "ammonia" of the fertilizer sack will be used at a loss.

GROWING CORN CONTINUOUSLY ON THE SAME LAND

In bringing the several blocks in this experiment into their respective places in the rotation, corn has been grown for three years in succession on Block M. The unfertilized yields for the first and last year are given below, in comparison with the similar yields on other blocks where the corn followed clover or soybeans:

		Bushels per acre 1911		1913
Rotation I	Block C	24.85	Block D	47.27
" II	" G	38.14	" E	54.39
" III	" L	20.57	" I	49.71
" "	" M	22.86	" M	26.71

Corn has been grown continuously and in rotation for 20 years at Wooster, with the following yields on unfertilized land by 5-year periods:

	Bushels per acre			
	1st 5 years	2nd 5 years	3rd 5 years	4th 5 years
Continuous	26.26	23.73	17.20	8.44
Rotation	31.89	30.82	31.04	20.31

The falling off in yield in the rotation corn during the last 5 year period was largely due to injury from white grub. The continuous corn did not suffer from this insect.

EXPERIMENTS WITH TOBACCO

Table VIII gives the results of the experiments with fertilizers and manure on tobacco, and Table IX gives the outcome of a comparison of varieties made under the supervision of A. D. Selby, with the assistance of Henry M. Wachter and True Houser of the Southwestern Test farm at Germantown.

TABLE VIII: Fertilizers and manure on TOBACCO and WHEAT in tobacco-wheat-clover rotation. Miami County Experiment Farm. Yield and increase per acre.

Plot No.	Treatment per acre	Tobacco				Wheat, 1913			
		1913		2-year average		Yield		Increase	
		Yield Lbs.	Increase Lbs.	Yield Lbs.	Increase Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.
1	None	1,240	...	1,590	...	46.42	3,707	....	...
2	Acid phosphate, 480 lbs	1,390	27	1,730	128	39.33	3,195	*5.03	*507
3	Acid phosphate, 480 lbs.; Muriate potash, 180 lbs.	1,630	143	1,820	206	40.75	3,475	*1.56	*222
4	None	1,610	...	1,625	...	40.25	3,692	....	...
5	Acid phosphate, 480 lbs.; Muriate of potash, 180 lbs.; Nitrate of soda, 240 lbs.	1,790	330	1,705	183	43.67	3,665	3.94	224
6	Acid phosphate, 480 lbs.; Muriate of potash, 180 lbs.; Nitrate of soda, 240 lbs.; Ground limestone, 2,000 lbs.	1,770	460	1,870	452	41.33	3,410	2.13	219
7	None	1,160	...	1,315	...	38.67	2,940	....	...
8	Acid phosphate, 240 lbs.; Muriate of potash, 90 lbs.; Nitrate of soda, 120 lbs.	1,430	330	1,515	265	39.67	3,035	*.11	145
9	Acid phosphate, 400 lbs.; Stable manure, 10 tons	1,440	400	1,452	268	37.33	3,030	*3.56	190
10	None	980	...	1,117	...	42.00	2,790	....	...
	Average unfertilized yield	1,247	...	1,411	...	41.83	3,282	....	...

*Decrease.

TABLE IX: Comparison of varieties of TOBACCO. Miami County Experiment Farm, 1913

Variety or selection	Yield per acre Lbs.	Increase per acre Lbs.
Zimmer Spanish (check)	1,640	...
81-4150	2,050	413
110-5012-6001	2,510	877
Zimmer Spanish (check)	1,630	...
170-3033	2,070	420
89-5017-No. 5	2,200	530
Zimmer Spanish (check)	1,690	...
307 hmp. 107	2,240	627
199-174-236	2,080	543
Zimmer Spanish (check)	1,460	...
Average Zimmer Spanish	1,605	...

VARIETY TESTING

CORN

In the variety testing of corn it is the aim to test the standard varieties adapted to the county. In 1913, eight varieties were grown, as reported in Table X. The comparative yield, as corrected by the check plots, is given in the third column. The Clarage stands slightly in the lead, with Reid second.

All but two of the varieties grown in 1913 were also grown in 1911. The two-year average yield is given in the fourth column. It will be noted that the Darke County Mammoth used upon the check plots stands first, with the Reid second. The check variety differs from that planted on Plot 10 in that it had been grown locally for two years previous. The latter was not as well acclimated.

TABLE X: Comparison of varieties of CORN. Miami County Experiment Farm.

Plot No.	Variety	1913 Actual yield per acre: Corn Bus.	1913 Actual yield per acre: Stover Lbs.	1913 Comparative yield Bus.	2-year average yield Bus.
1	Leaming	48.36	2,600	48.61	44.07
2	Check (Darke County Mammoth)	58.14	2,400	.....	.....
3	Clarage	59.57	1,550	59.91	47.69
4	White Cap	55.43	2,950	55.86	.....
5	Check	57.86	3,200	.....	.....
6	Cook's No. 75	57.57	2,850	57.29	48.17
7	Reid (Orcutt)	60.93	2,950	59.84	49.07
8	Check	60.29	3,150	.....	.....
9	Ohio 84 (Early Reid)	48.50	2,500	47.60	40.00
10	Darke County Mammoth (Station)	53.50	2,750	53.60	48.90
11	Check	57.29	3,350	.....	.....
12	Leaming (Scott)	47.43	2,700	48.53	.....
	Average yield of check plots	58.39	.....	.....	50.49

WHEAT

Two distinct variety tests of wheat were conducted in 1912-13. One set of 12 plots was grown after tobacco. The same variety of wheat—the Velvet Chaff—was used as check in each set. It is of interest to note that the checks average 6.05 bushels higher following tobacco. One other variety was the same in each test, viz: Gypsy Selection 6100, and it gives an increased yield of 7.44 bushels after tobacco. Similar results are secured in northern Ohio in growing wheat after potatoes. Better soil conditions with respect to moisture, nitrates and seed bed probably account for this result.

In the 12-plot test the Rudy, Gypsy Selection 6100 and Nigger lead, with but a small fraction of a bushel difference.

In the tobacco-wheat-clover test three pedigreed selections of wheat which the Experiment Station has developed in its head-row testing work at Wooster, are compared, side by side, with the bulk varieties from which they were selected. In each instance the pedigreed strain exceeds the original, and in the case of Poole Selection 6400 the margin is quite remarkable.

The Miami County wheat yields were exceptionally good in 1913. It should be stated that in 1912 only two varieties survived the winter, viz.; the Turkey Red and the Kharkof. These are unusually hardy Russian varieties which will endure more hardship than our American varieties, but do not usually yield as well in Ohio of a normal season.

The yields at Wooster for the year 1913 are recorded for comparison.

TABLE XI: Comparison of varieties of WHEAT. Actual and comparative yields per acre.

Plot No.	Variety	Miami county: Grain: Actual	Miami county: Grain: Comparative	Miami county: Straw: Actual	Wooster: Comparative 1913
		Bus.	Bus.	Lbs.	Bus.
1	Nigger	44.67	42.94	5,820	34.26
2	Check (Velvet Chaff)	38.50	.....	4,190	.....
3	Gypsy Selection No. 6100	44.33	43.16	5,710	32.77
4	Mediterranean	39.06	38.47	5,655	28.91
5	Check	36.83	.....	5,165	.....
6	Rudy	42.92	43.22	4,225	33.10
7	Turkey Red	37.92	38.58	4,885	28.83
8	Check	35.75	.....	4,805	.....
9	Fultz Selection No. 5309	40.50	41.44	4,740	35.13
10	Goens	37.06	37.94	5,175	31.85
11	Check	36.00	.....	5,065	.....
12	Valley	41.33	42.10	5,900	29.50
	Average of checks	36.77	.....	4,806	29.55

TABLE XII: Pedigreed wheat test.

Plot No.	Variety	Miami County			Wooster
		Grain		Straw	Comparative 1913
		Actual	Comparative	Actual	
		Bus.	Bus.	Lbs.	Bus.
1	Check (Velvet Chaff)	42.67	.....	6,240	.....
2	Gypsy	46.33	45.37	6,810	29.04
3	Gypsy Selection 6100	52.67	50.60	7,240	32.77
4	Check	46.00	.....	6,890	.....
5	Poole	46.08	44.57	6,135	34.90
6	Poole Selection 6400	55.33	55.49	5,230	40.45
7	Check	41.00	.....	5,680	.....
8	Fultz	40.00	41.60	5,150	31.53
9	Fultz Selection 8106	41.50	42.88	5,160	33.74
10	Check	41.67	.....	5,800	.....
	Average checks	42.82	.....	....	29.55

OATS

Seven varieties of oats, Oderbrucker barley and emmer (sometimes called speltz) are included in the oats variety test. The Big Four variety leads, both in the 1913 test and in the 2-year average, while the Swedish Select and Silver Mine are close seconds.

Emmer gives a remarkable yield in 1913—much better than in 1912. In comparing emmer with barley and oats it should be stated that the yield is recorded at 32 lbs. per bushel for both oats and emmer, and 48 lbs. for the barley. Emmer is supposed to weigh more than oats, but at Wooster it has tested about the same.

The yield of the same varieties for the last six years at Wooster is included for comparison.

TABLE XIII: Comparison of varieties of OATS. Miami County Experiment Farm.

Variety	Comparative yields			
	1913		2-yr. average Miami	6-yr. average Wooster
	Grain	Straw		
	Bus.	Lbs.	Bus.	Bus.
Ohio 7009 (Sixty Day)	44 14	1,730	59.17	66.52
Ohio 6203 (Siberian)	60.75	4,270	67.95	69.55
Swedish Select	61.12	3,480	69.85	56.70
Big Four	62.99	3,830	70.58	65.50
Silver Mine	61.07	2,705	69.41	65.42
Ohio 6222 (Improved American)	51.87	2,990	.....	66.18
Emmer	61.55	2,930	48.75	18.45
Oderbrucker Barley	36.06	2,770	34.06	18.92
Wideawake—average of 4 check plots	57.114	2 710	64.25	55.74

SOYBEANS

The increasing importance of the soybean to Ohio agriculture, and in particular to the southern half of the state, has suggested the testing of rotations including this crop, as well as different varieties of soybeans in the regular variety tests. Nine varieties

were tested in 1913, with the results recorded in Table XIV, second column. Six of these varieties had been tested in 1912, and the average yield for the two seasons is recorded in column 3.

The New Era cowpeas were grown both years for seed. Their average yield is less than one-half that of soybeans.

For comparison, the 3-year average yields of these varieties, as grown at Wooster, are given.

TABLE XIV: Comparison of varieties of SOYBEANS.

Variety	Color of beans	Yield per acre Miami Co. 1913	Average yield per acre	
			2-year Miami Co.	3-year Wooster
		Bus.	Bus.	Bus.
Ohio 9100 (Ito San)	Yellow	12.81	19.74	21.79
Mongol	Yellow	15.29	27.64	27.58
Chestnut	Yellow	16.93	.....	27.79
Ohio 9035	Brown	16.67	19.83	28.51
Ebony	Black	15.62	21.89	24.42
Ohio 7496	Yellow	20.26	.....	29.25
Ohio 9016	Yellow	17.12	.....	30.64
New Era Cowpeas	Mottled	8.67	8.58	6.77
Medium Green (check) average of 4 plots	Green	15.81	17.90	25.83

SWINE HUSBANDRY

By THE DEPARTMENT OF ANIMAL HUSBANDRY

Pursuant to the plan outlined in Bulletin 241, an experiment has been begun in the raising of hogs on corn and forage crops to be harvested by what is known as the "hogging down" system. Nineteen acres of land has been set aside for this purpose, and divided by wire fences into a blue-grass pasture of 4 acres and 5 lots of three acres each to be cropped in a 5-year rotation as follows:

First year, corn; second year, corn; third year, rape and soy beans; fourth year, rye; fifth year, clover.

The green crops are to be supplemented with grain and tank age when necessary.

Seventy-five pigs were raised in the spring of 1913 and used in pasturing clover and hogging down rye and corn. Owing to the fact that the pigs came rather late in the spring and to a lack of facilities for doing experimental work, no very definite data were secured from the pasturing of the clover or the hogging down of the rye; however, some data were secured from hogging down corn. Two three-acre plots were hogged down with 60 pigs, all the pigs having access to only one plot at a time. The following is a summary of the results secured.

Results secured from hogging down 6 acres of corn with 60 pigs:

Initial weight, September 6, 1912		4564.5 lbs.
Final weight, October 18, 1913[1]		8264.5 lbs.
Total gain, 42 days[1]		3801.0 lbs.
Average daily gain per pig		1.51 lbs.
Feed consumed aside from standing corn	Shelled corn	335.0 lbs.
	Tankage	754.5 lbs.
Cost of feed consumed aside from standing corn[2]	Shelled corn \$3.35; Tankage \$18.86	\$22.21

Return per acre:

Hogs @ 6c per pound	\$34.31
Hogs @ 7c per pound	\$40.64
Hogs @ 8c per pound	\$46.98

The pigs used averaged 76 pounds in weight when they were turned on the corn and made an average gain of 1.51 pounds daily per pig during the 42 days required to hog down the 6 acres, and, with hogs at 6, 7 and 8 cents per pound live weight, showed a return of \$34.31, \$40.64 and \$46.98 per acre respectively for the standing corn. It was estimated that the corn hogged down would yield about 45 to 50 bushels per acre. In addition to the standing corn, the pigs received three-tenths of a pound of tankage daily per pig, and some shelled corn when they were first turned on the standing corn and again at the close of the hogging down period when the corn on the plot was becoming very scarce. In regard to the net returns per acre as shown above it should be noted that, while charge is made for the tankage and shelled corn consumed by the pigs, yet all *profit* from the project is credited to the standing corn.

It was apparent from the season's work that a rotation furnishing a larger proportion of corn than the five-year rotation of corn, corn, rape and soybeans, rye, and clover, as started last year, would be better suited for this work, and the rotation has been changed to a four-year rotation of corn, corn, wheat or rye, and clover, and one of the five original three-acre plots is to be kept in continuous corn culture with rape and possibly rye seeded in the corn at the last cultivation, the corn to be hogged down each year. In view of the fact that rye soon becomes woody and tough, furnishing palatable green forage for a relatively short time, and that it is not especially well suited for hogging down as was done in 1913, a plan to allow the rye to mature and harvest it, or to use wheat instead of rye, is being considered.

The former four-acre bluegrass plot is being cut down to two acres of bluegrass, the other two acres being devoted to one acre each of alfalfa and rape.

[1]One pig taken out October 13, weight 101 pounds.
[2]Corn 56c per bushel. Tankage \$50 per ton.

THE CLERMONT COUNTY EXPERIMENT FARM

SECOND ANNUAL REPORT, FOR 1913

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JUNE, 1914.

BULLETIN 275

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

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[1]With leave of absence. [2]In cooperation with Weather Service, U. S. Department of Agriculture.
[3]In cooperation with Bureau of Plant Industry, U. S. Department of Agriculture.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 277 JUNE, 1914

OHIO WEATHER FOR 1913

BY J. WARREN SMITH AND C. A. PATTON

EXPLANATORY

BY THE DIRECTOR

The extension of the work of the Experiment Station over the state, through the district and county experiment farms, makes it necessary that its weather records should be state-wide in their application. Hitherto the only attempt at such application has been to give the average rainfall and temperature for the entire state for comparison with the observations taken at the main station at Wooster, but it is now possible, through the cooperation of Prof. J. Warren Smith, Section Director for Ohio of the U. S. Weather Bureau, to supplement these records with a series of diagrammatic maps, showing at a glance the comparative weather conditions for the different sections of the state.

These maps will be followed by the usual summary tables.

Mean temperature, January, 1913

Figure 1. Average temperature for January, 1913. The mean temperature for the state was 36.0°. The highest local monthly mean was 43.2° in Lawrence county, and 43.0° in Meigs county; the lowest local monthly mean was 29.9° in Fulton county. The highest temperature reported was 70° in Meigs county on the 20th and 31st, and lowest was 3° in Wood county on the 9th. The month was marked by frequent and unusually warm days, being the warmest January on record since 1890 when the mean temperature was 38.8°.

Temperature departures, January, 1913

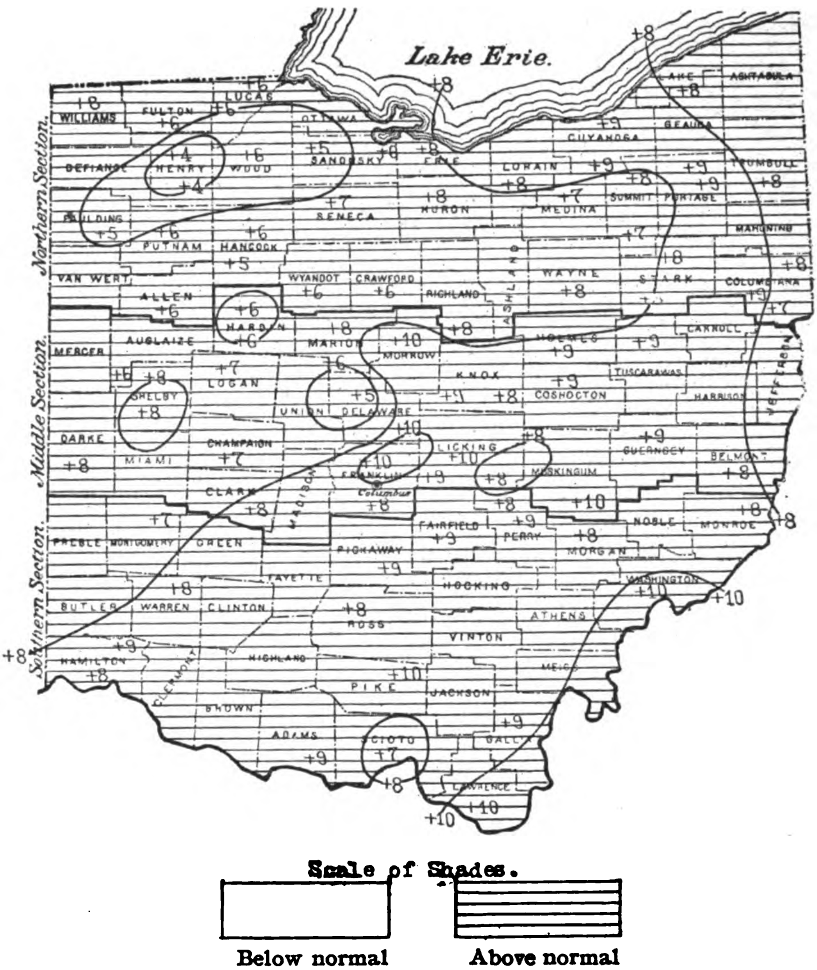


Figure 2. Temperature departures from the normal for January, 1913. The temperatures were far above normal throughout the whole state, ranging from 3.9° above the normal in Henry county, to 11.1° in Washington county, 10.2° in Lawrence county, and 10.3° in Franklin county. The state as a whole averaged 7.8° above the normal.

Precipitation, January, 1913

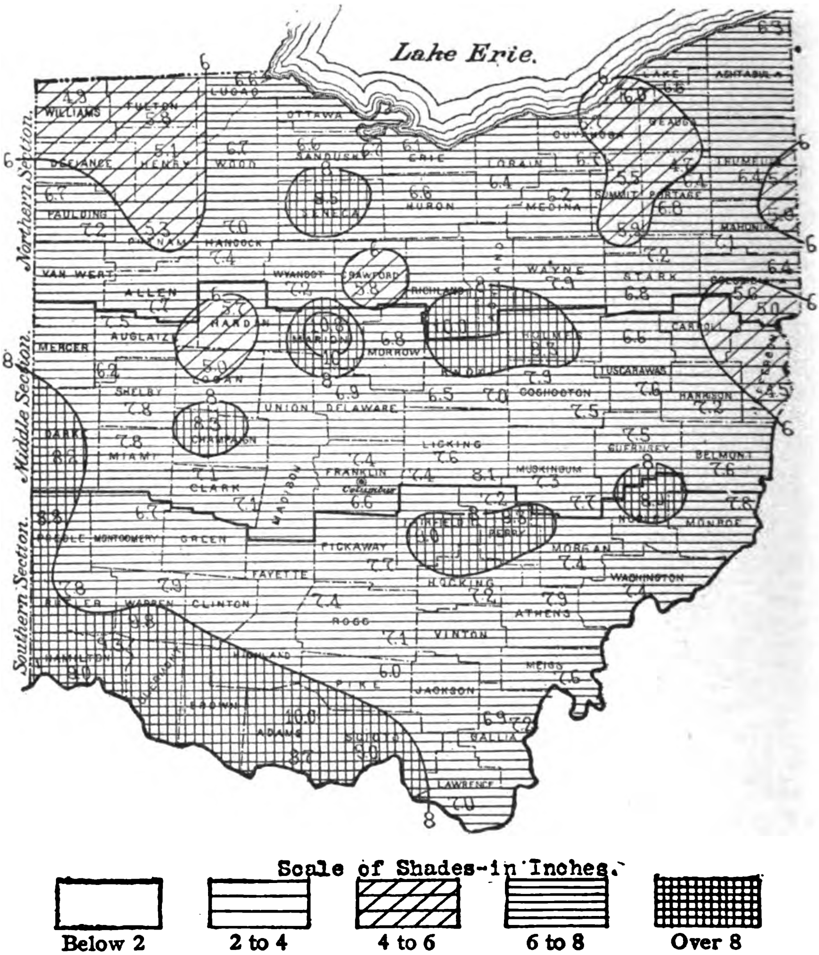
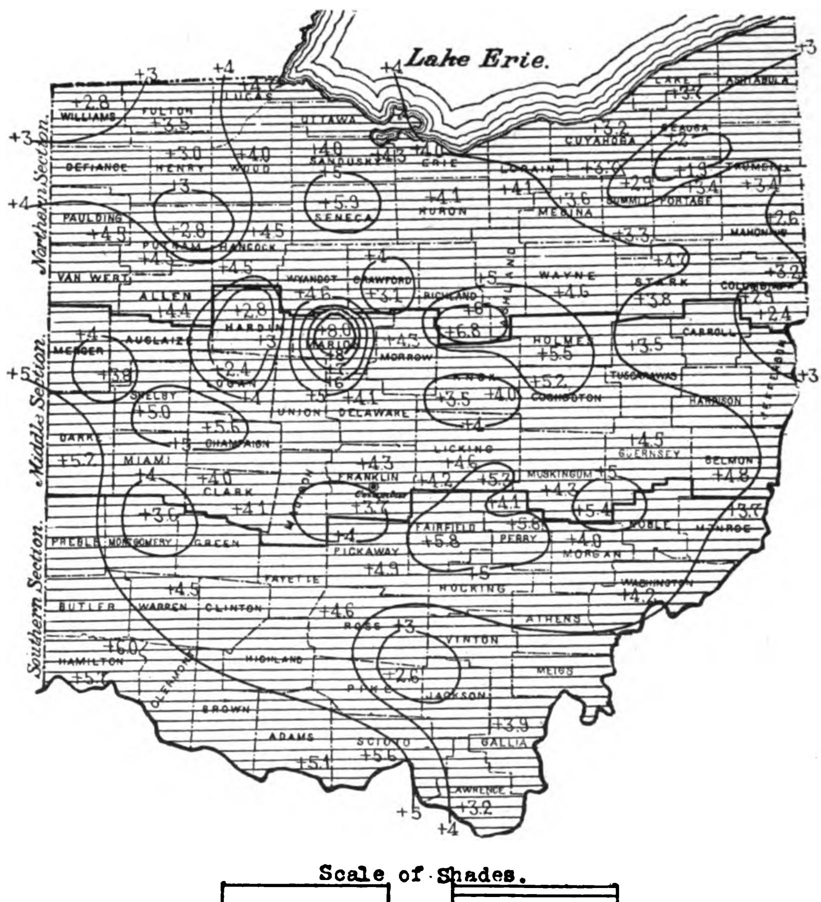


Figure 3. Precipitation during January, 1913. The average precipitation for the state was 7.01 inches, making the month by far the wettest January on record. Not only was the January record broken, but the state averages for any other month have been larger only five times in the last fifty years. The largest amount reported was 10.80 inches in Marion county, and least was 4.50 inches in Jefferson county. The precipitation was heaviest in the southeastern counties and in scattered sections of the central part of the state. The northeastern and northwestern counties showed the lightest falls. The heavy rainfall caused high water in all streams and rivers during the first part of the month.

Precipitation departures, January, 1913



Scale of Shades.

Below normal Above normal

Figure 4. Departures from the normal precipitation for January, 1913. The average departure from the normal precipitation for the state was 4.17 inches, ranging from 1.90 inch in Portage county to 8.01 inches in Marion county. The number of rainy days averaged between 15 and 20 for nearly every station in the state, so that the mild temperatures were of little value for the carrying on of outdoor work.

Snowfall, January, 1913

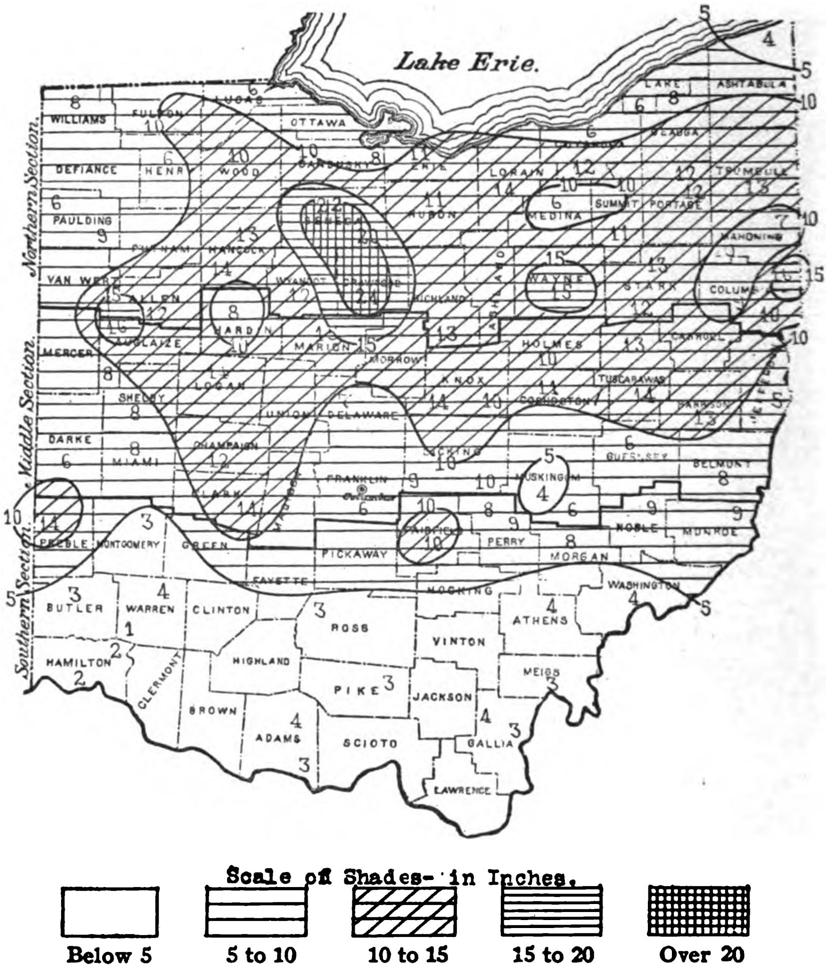
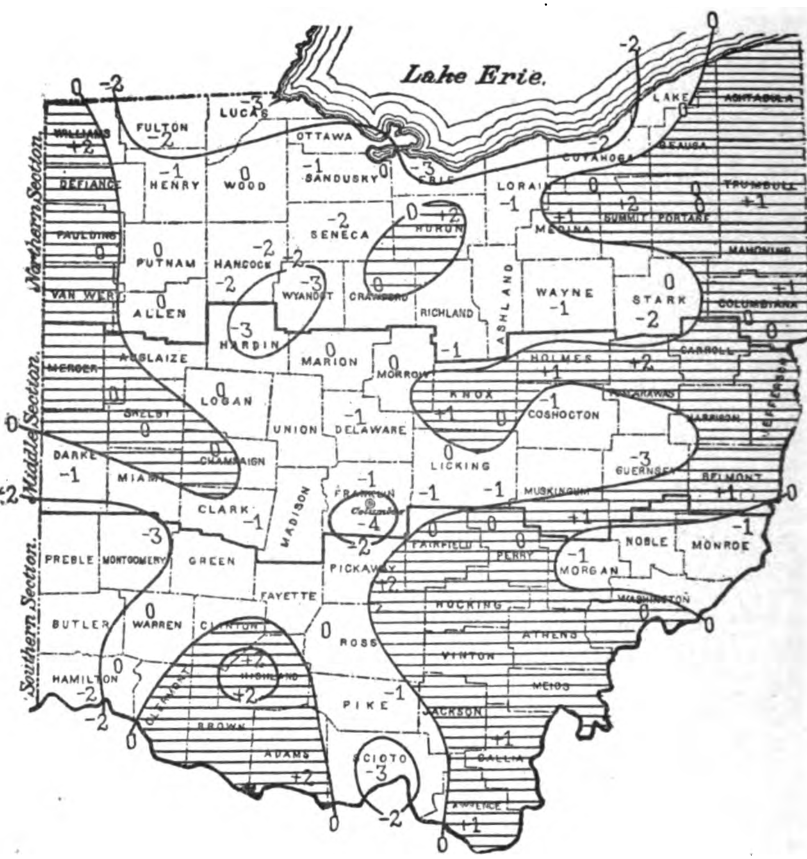


Figure 5. Snowfall for January, 1913. The average snowfall for the state was 8.6 inches. It was below the normal in nearly all except the northern counties, nearly all the precipitation falling as rain in the southern and border counties. What snow did fall remained on the ground but a short time, although in some of the northern counties the ground was covered from the third to the fifth, and on the twenty-eighth and twenty-ninth. The greatest amount for the month was 24.0 inches in Crawford county.

Mean temperature, February, 1913

Figure 6. Average temperatures for February, 1913. The mean temperature for the state was 26.7°. The highest local monthly mean was 35.0° degrees in Lawrence county and the lowest local monthly mean was 22.4° in Fulton county. The highest temperature reported was 77°, in Belmont county on the 21st, and the lowest was 15° below zero in Perry county on the 6th. Low temperatures prevailed during the first half of the month, but during the last half the weather was considerably milder, especially from the 19th to the 22nd.

Temperature departures, February, 1913



Scale of Shades.

Below normal | Above normal

Figure 7. Temperature departures from the normal for February, 1913. The temperatures averaged 0.5° below normal for the state as a whole, ranging from 3.8° below normal in Franklin county to 2.1° above normal in Highland county. The month showed a sharp contrast to January, being nearly 10° colder.

Precipitation, February, 1913

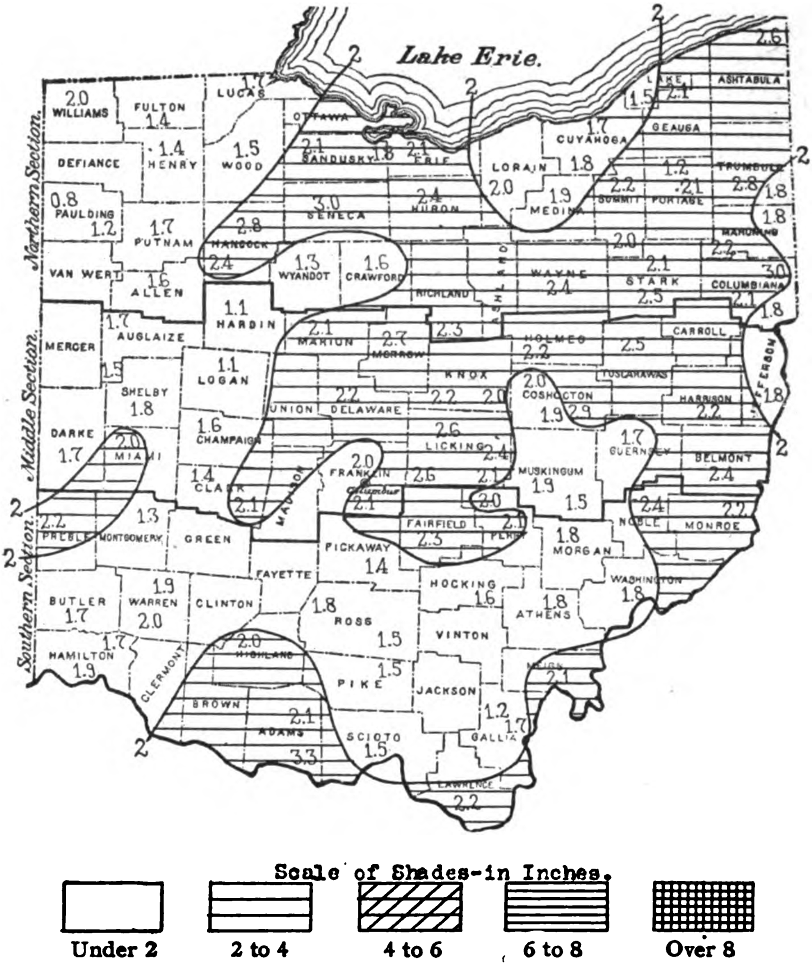
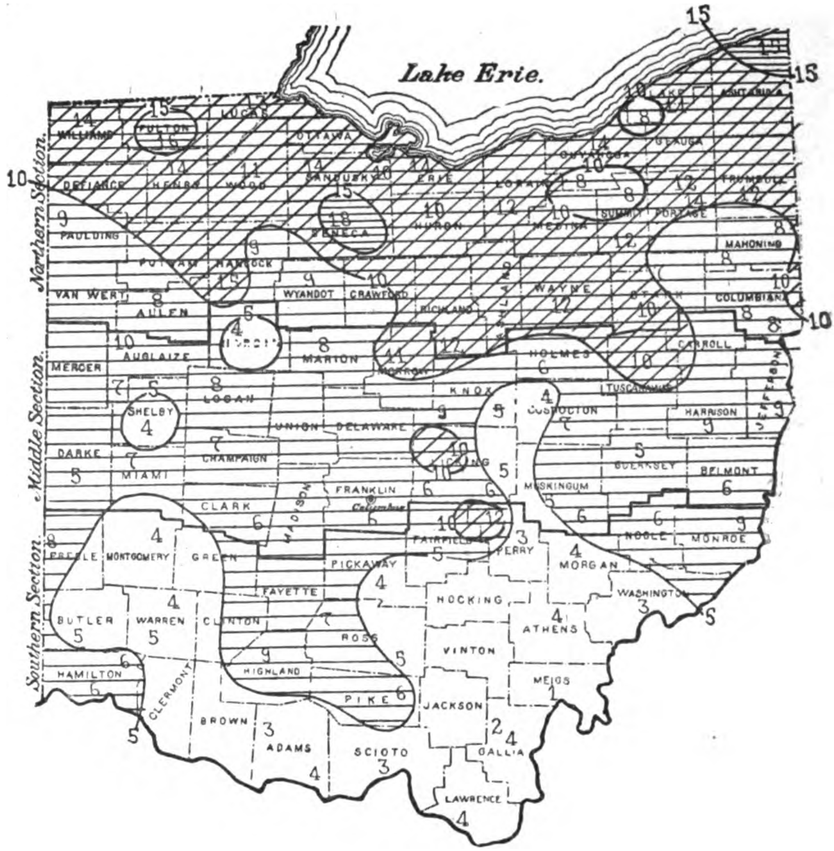


Figure 8. Precipitation during February, 1913. The average precipitation for the state was 1.94 inch, ranging from 3.32 inches in Adams county to 0.75 inch in Paulding county. With the exception of the 3rd the precipitation was scattered and quite light until near the close of the month.

Precipitation departures, February, 1913

Figure 9. Departures from the normal precipitation for February, 1913. The average departure from the normal precipitation for the state was 0.77 inch below normal, ranging from 2.15 inches below normal in Pike county to 0.36 inch above normal in Columbiana county. Precipitation was in the form of snow during practically all of the first three weeks and was mostly in the form of rain during the last week. The number of rainy days averaged 8.

Snowfall, February, 1913



Scale of Shades-in Inches.

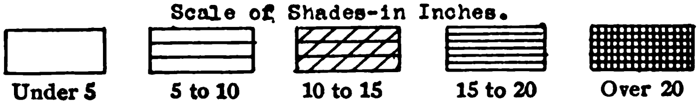


Figure 10. Snowfall for February, 1913. The average snowfall for the state was 6.9 inches, ranging from 18 inches in Seneca county to 1 inch in Meigs county. The snowfall averaged above normal in nearly all the northern counties and in scattered counties throughout the south. The snow of the 2nd and 3rd was exceptionally dry. The ground was generally well protected by snow from the 3rd to the 10th of the month when the coldest weather was experienced.

Mean temperature, March, 1913

Figure 11. Average temperatures for March, 1913. The mean temperature for the state was 40.1°. The highest local monthly mean was 47.6° in Gallia and in Lawrence counties; the lowest local monthly mean was 34.7° in Fulton county. The highest temperature reported was 80° in Adams county on the 14th and the lowest 8° below zero in Portage county on the 8th. Unusually warm weather for the time of year was experienced on the 14th and 20th. The 7th was the coldest day at most stations, although cold spells occurred on the 16-17th, 22nd, and 27-29th.

Temperature departures, March, 1913

Scale of Shades

Below normal Above normal

Figure 12. Temperature departures from the normal for March, 1913. The state as a whole averaged 0.9° above the normal, ranging from 3.2° below the normal in Henry county to 3.8° above the normal in Cuyahoga county and 4.1° above the normal in Washington county.

Precipitation, March, 1913

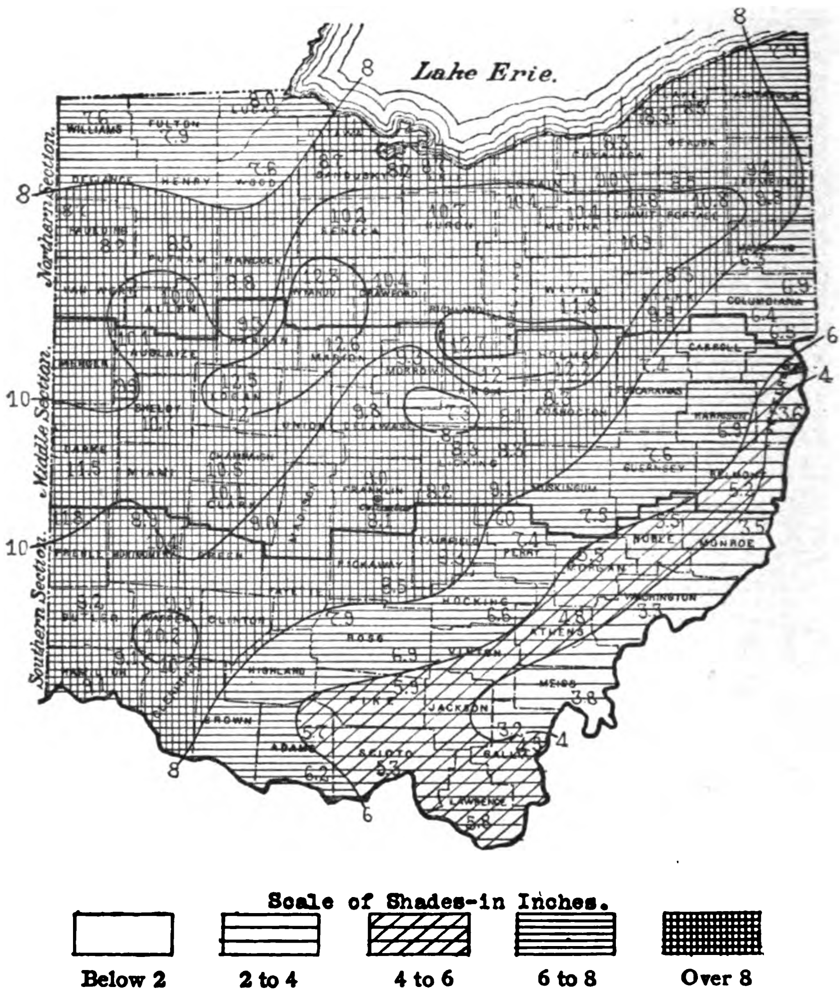


Figure 13. Precipitation for March, 1913. The average precipitation for the state was 8.40 inches, making the month the wettest March on record. The state averages for the other months have been greater in but two instances in the last fifty years. The largest amount reported was 12.68 inches in Richland county, and the least was 3.18 inches in Gallia county. The area of heaviest precipitation extended across the state from southwest to the northeast and followed closely the boundary line between the Lake Erie and Ohio River watersheds.

During the first three weeks the precipitation was rather light but from the 23rd to 27th rain fell almost continuously, and during much of the time at an excessive rate. At several stations in the middle-northern counties over ten inches fell in these five days, and over twelve inches during the month.

Precipitation departures, March, 1913

Scale of Shades.

Below normal | Above normal

Figure 14. Departures from the normal precipitation for March, 1913. The average departure from the normal precipitation for the state was 5.28 inches above the normal, ranging from 1.15 inch below normal in Monroe county to 9.01 inches above normal in Logan county, 9.07 inches above normal in Wyandot county, and 9.19 inches above normal in Marion county. The average number of rainy days was 13.

The heavy rains of the 23rd-27th caused the most destructive flood in the history of the state. The estimated property loss in Ohio due to this flood was $113,660,000, and there were 467 lives lost. The damage to agricultural interests was very great.

Snowfall, March, 1913

Figure 15. Snowfall for March, 1913. The average snowfall for the state was 5.1 inches, ranging from 16.3 inches in Williams county and 15.5 inches in Fulton county to a trace in some of the southern counties. It averaged above normal in nearly all of the northern counties, but was considerably below normal in the southern counties.

Mean temperature, April, 1913

Figure 16. Average temperatures for April, 1913. The mean temperature for the state was 50.0°. The highest local monthly mean was 55.0° in Lawrence county, and the lowest local monthly mean was 46.1° in Lake county. The highest temperature reported was 90° in Columbiana and Meigs counties, and the lowest was 18° in Portage county. Cloudy and cool weather prevailed during the first two weeks, and the 20th and 21st were unseasonably cool. The last few days were also cool but the rest of the month was bright and pleasant.

Temperature departures, April, 1913

Figure 17. Temperature departures from the normal for April, 1913. The state as a whole averaged 0.6° above the normal, ranging from 2.7° below normal in Hardin county to 2.6° above normal in Holmes county, and 3.4° above the normal in Summit county.

Precipitation, April, 1913

Figure 18. Precipitation for April, 1913. The average precipitation for the state was 3.35 inches. The largest amount was 5.50 inches in Butler county, although 5.36 inches was reported in Clark county. The least was 1.87 inch in Mahoning county. The greater part of the rainfall occurred during the first half of the month, although on the 26-28th quite general rains prevailed. The area of heaviest precipitation extended from the southwestern corner of the state to a point slightly south of the western end of Lake Erie. Practically no snow fell during the month.

Precipitation departures, April, 1913

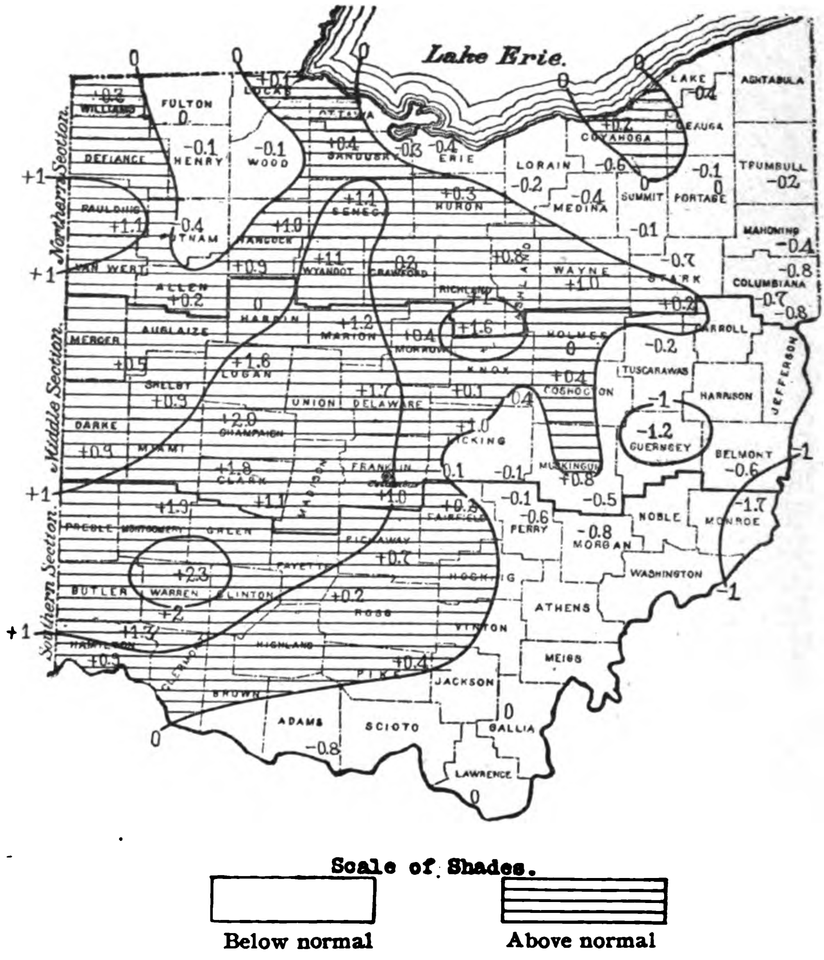


Figure 19. Departures from the normal precipitation for April, 1913. The average departure from the normal precipitation was 0.30 inch above the normal, ranging from 1.69 inch below normal in Monroe county to 2.33 inches above normal in Warren county. The number of rainy days averaged 10; no excessive precipitation was reported.

Mean temperature, May, 1913

Figure 20. Average temperature for May, 1913. The mean temperature for the state as a whole was 60.3°, ranging from 55.8° in Lake county, and 56.0° in Ashtabula county, to 65.8° in Hamilton county. The highest temperature reported was 95° in Meigs county on the 4th, and the lowest was 23° in Columbiana county on the 11th and 12th, and in Coshocton county on the 11th.

At nearly all stations the warmest weather of the month was experienced during the first five days, a week of cooler weather followed with record breaking minimum temperatures on the 11th at six stations, while the previous lowest May record was equalled at ten others on the same date. More seasonable temperatures prevailed from the 12th to the 18th, but there were only two or three days from the 19th to the close of the month with the temperature above normal.

Temperature departures, May, 1913

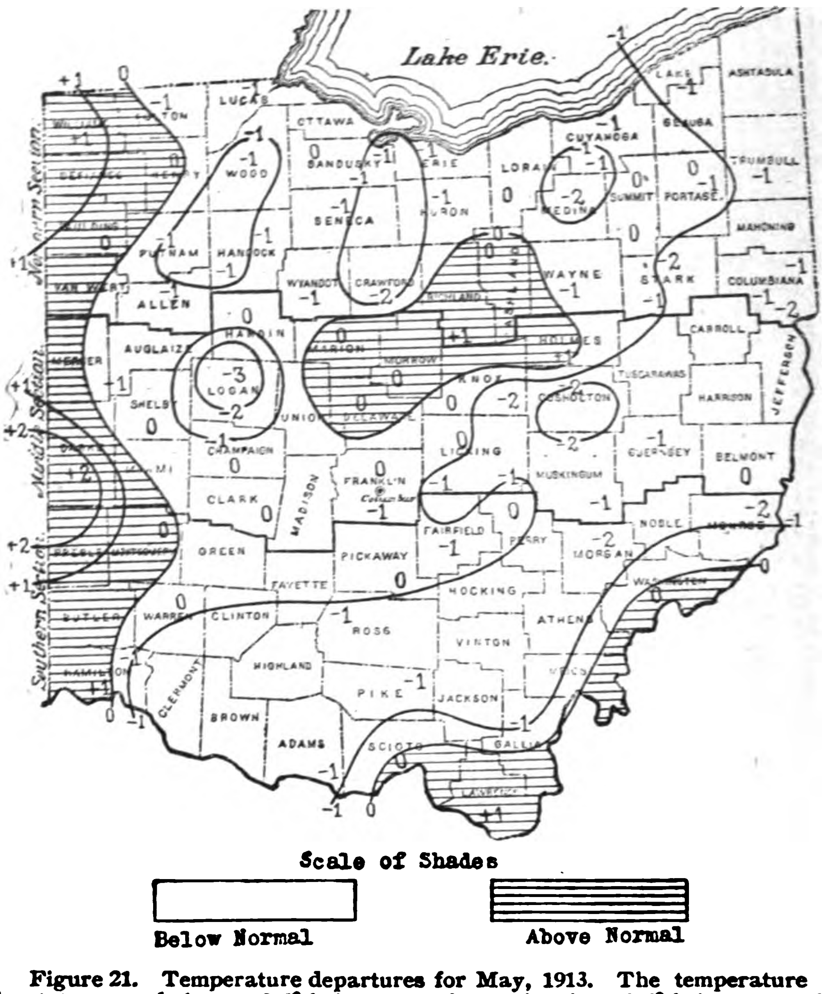


Figure 21. Temperature departures for May, 1913. The temperature for the state as a whole was 0.6° below normal, ranging from 2.6° below normal in Logan county to 2.2° above normal in Darke county. A narrow strip along the western edge of the state, portions of a few of the southeastern counties along the Ohio River, and a few of the north-central counties were above normal but all the rest were below normal.

Precipitation, May, 1913

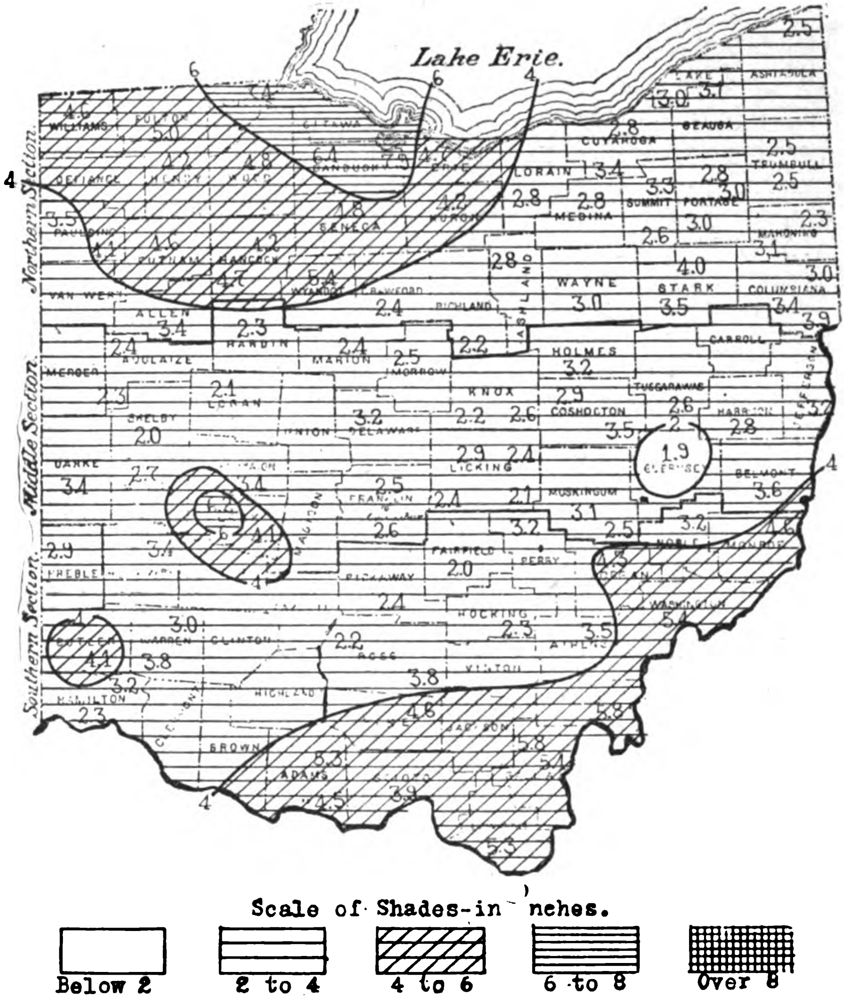


Figure 22. Precipitation for May, 1913. The average precipitation for the state as a whole was 3.53 inches., ranging from 7.94 inches in Sandusky county to 1.86 inch in Guernsey county. The first part of the month was comparatively dry, but during the remainder of the month showers were frequent, and in the northwestern and southeastern, as well as in Clark and in Butler counties, were heavy. At Toledo, in Lucas county, 3.57 inches fell in 24 hours, on the 26th and 27th. The rainfall in the latter part of the month hindered farm work greatly, especially delaying corn planting.

Precipitation departures, May, 1913

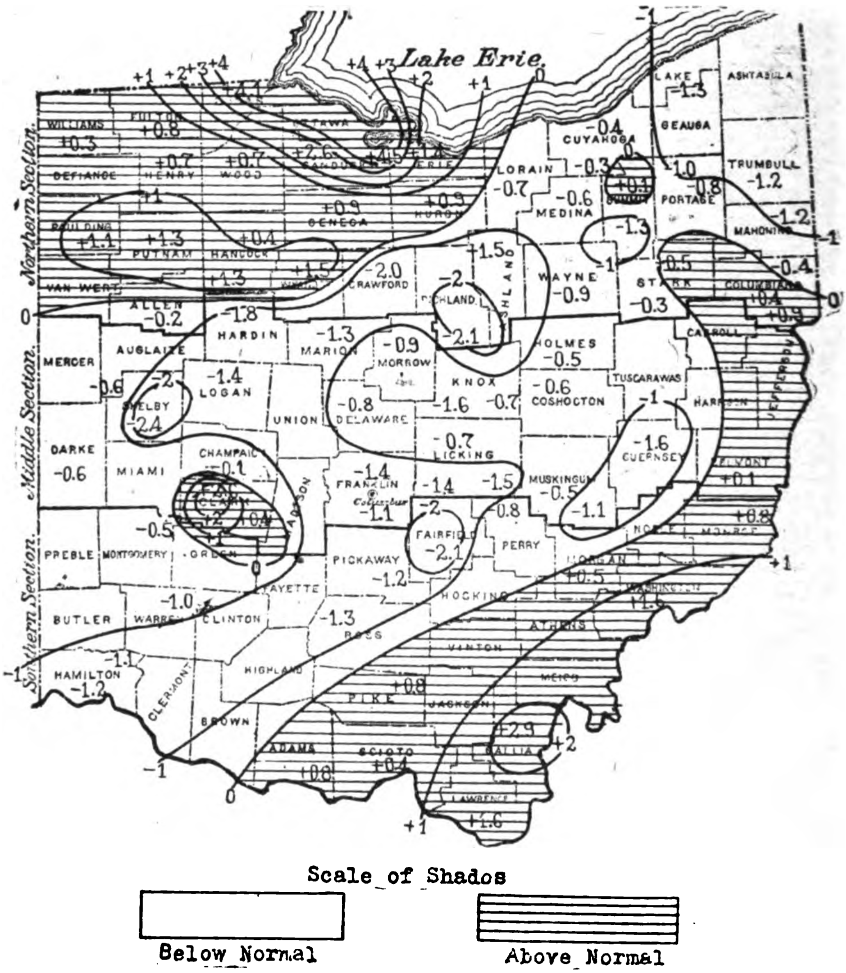


Figure 23. Precipitation departures for May, 1913. The precipitation for the state as a whole averaged 0.12 inch below the normal, ranging from 4.49 inches above normal in Sandusky county to 2.35 inches below normal in Shelby county. The average number of rainy days was 10.

Mean temperature, June, 1913

Figure 24. Average temperature for June, 1913. The mean temperature for the state was 69.8°. The highest local monthly mean was 74.8° in Hamilton county; the lowest local monthly mean was 65.0° in Portage county. The highest temperature reported was 105° in Columbiana county on the 30th, and the lowest was 29° in Portage county on the 10th.

The first half of the month was generally cool, and the last half generally warm. Record breaking minimum temperatures for the month of June were experienced at 4 stations, and 6 others equalled their previous June record. The maximum temperature records for June were broken at 12 stations and were equalled at 11 others. During the latter part of the month an unusually large number of heat prostrations occurred.

Temperature departures, June, 1913

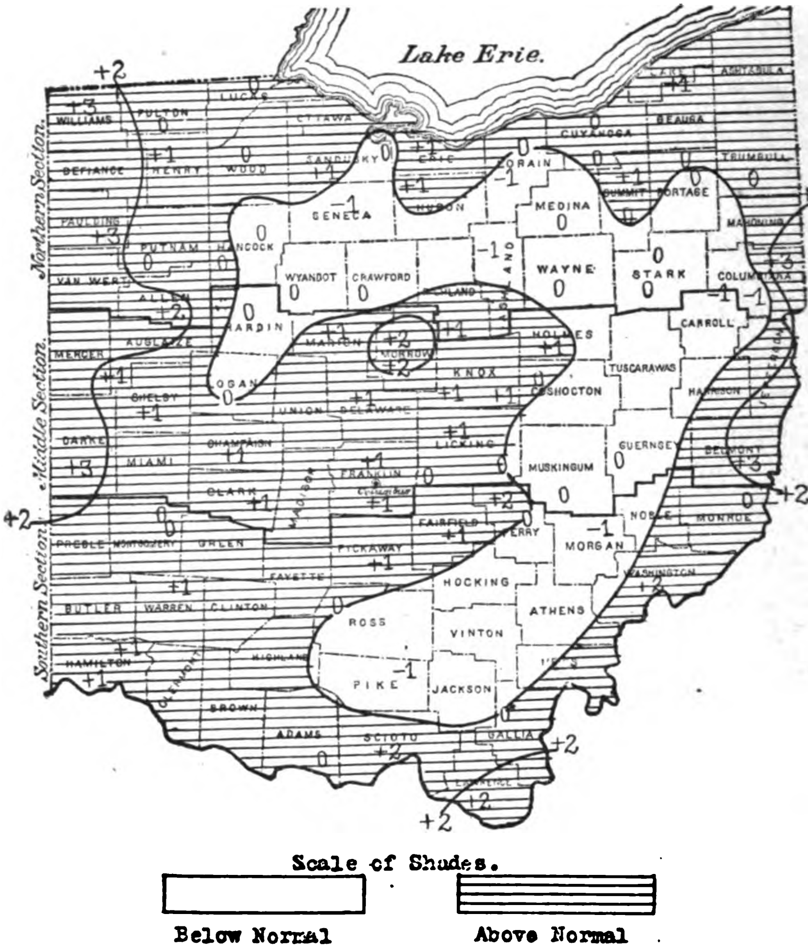


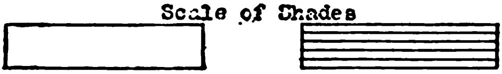
Figure 25. Temperature departures from the normal for June, 1913. The temperature was above normal for most stations throughout the state, ranging from 3.2° above normal in Columbiana county to 1.1° below normal, also in Columbiana county. The state as a whole was 0.6° above normal.

Precipitation, June, 1913

Figure 26. Precipitation during June, 1913. The average precipitation for the state as a whole was 1.87 inch, making this one of the driest Junes on record. Several stations reported less than one inch for the whole month, Lima being least with only 0.36 inch. Marietta had the heaviest precipitation, 4.94 inches. In nearly all instances the rainfall occurred with thunderstorms, and in many places these storms were severe, considerable damage being done by wind, lightning and hail.

Precipitation departures, June, 1913

Scale of Shades



Below Normal

Above Normal

Figure 27. Departures from the normal precipitation for June, 1913. The precipitation for June was 2.04 inches below normal, ranging from 4.18 inches below normal in Perry county to 0.71 inch above normal in Washington county. The precipitation was above normal at only two stations in the whole state. The number of rainy days averaged 6.

Mean temperatures, July, 1913

Figure 28. Average temperature for July, 1913. The mean temperature for the state was 74.5°. The highest local monthly mean was 103° reported in Clark county on the 29th, and in Hamilton and Montgomery counties on the 30th; the lowest local monthly mean was 40° in Portage county on the 11th.

This was one of the warmest Julys on record in this state, the state average having been higher but five times in the past thirty-one years. The month began and ended with excessively high temperatures, but from the 6th to the 26th the temperatures were generally close to normal. Many prostrations and deaths resulted during the two hot periods.

Temperature departures, July, 1913

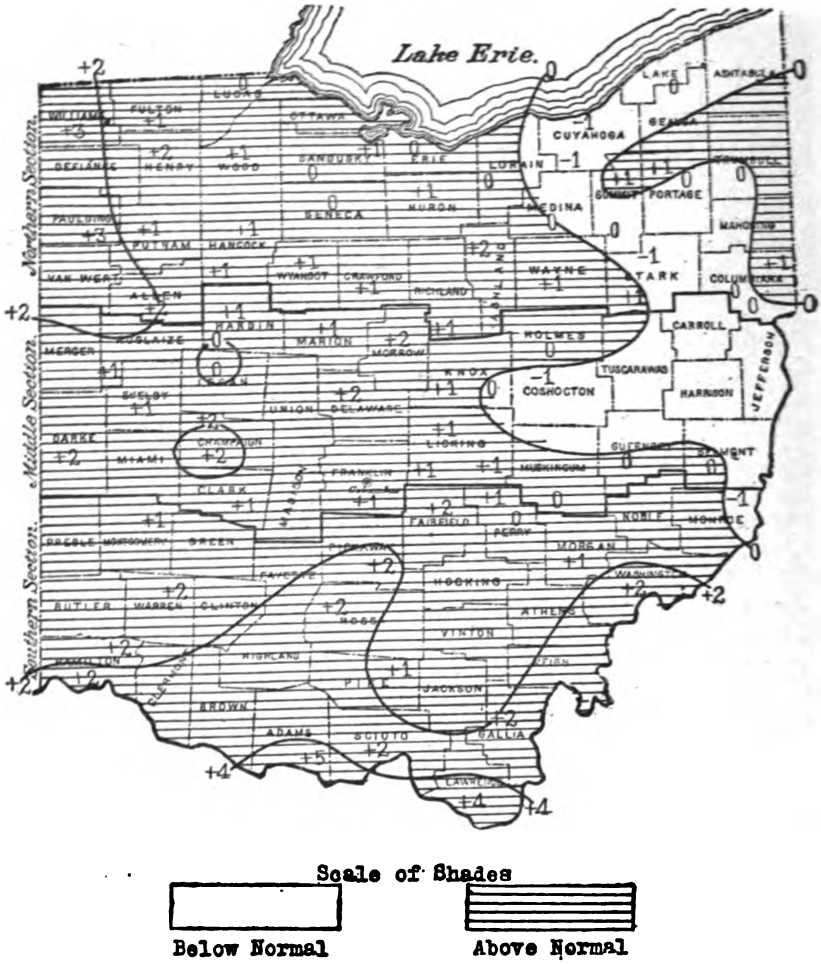


Figure 29. Temperature departures from the normal for July, 1913. The temperature was above normal at most stations throughout the st ate, rangng from 3.4° above normal in Paulding county to 0.8° below normal in Stark iand Coshocton counties. The state as a whole averaged 1.0° above normal.

The average number of clear days was 16, against an average of 12 partly cloudy, and 3 cloudy days. The percentage of sunshine was also above normal.

Precipitation, July, 1913

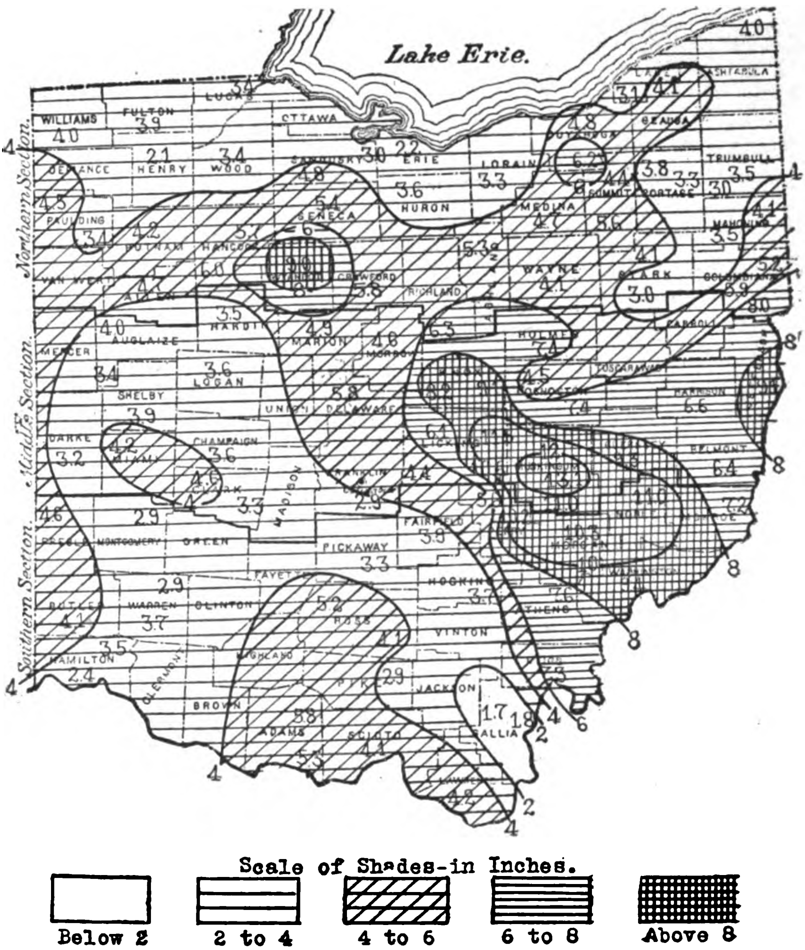


Figure 30. Precipitation during July, 1913. The average precipitation for the state as a whole was 5.20 inches, making this one of the wettest Julys on record. Only three times in the past thirty-one years has this precipitation average been greater. Thurman, in Gallia county, had the smallest monthly rainfall, reporting only 1.71 inch. Zanesville, in Muskingum county, reported 13.12 inches, considerably over half of which fell on the 14th and 15th of the month. On the night of the 13th and morning of the 14th an almost unprecedented rainfall for this state occurred over the Muskingum watershed, causing the lower Muskingum river to rise about 5 feet above flood stage. Also all the smaller streams overflowed their banks, some of them going higher than ever before. Heavy damage was done to crops, railroads, highways and bridges.

Heavy rainfalls also occurred over the Sandusky river valley on the same date, and caused considerable damage. Several severe thunderstorms were reported in the state during the month, heavy loss resulting.

Precipitation departures, July, 1913

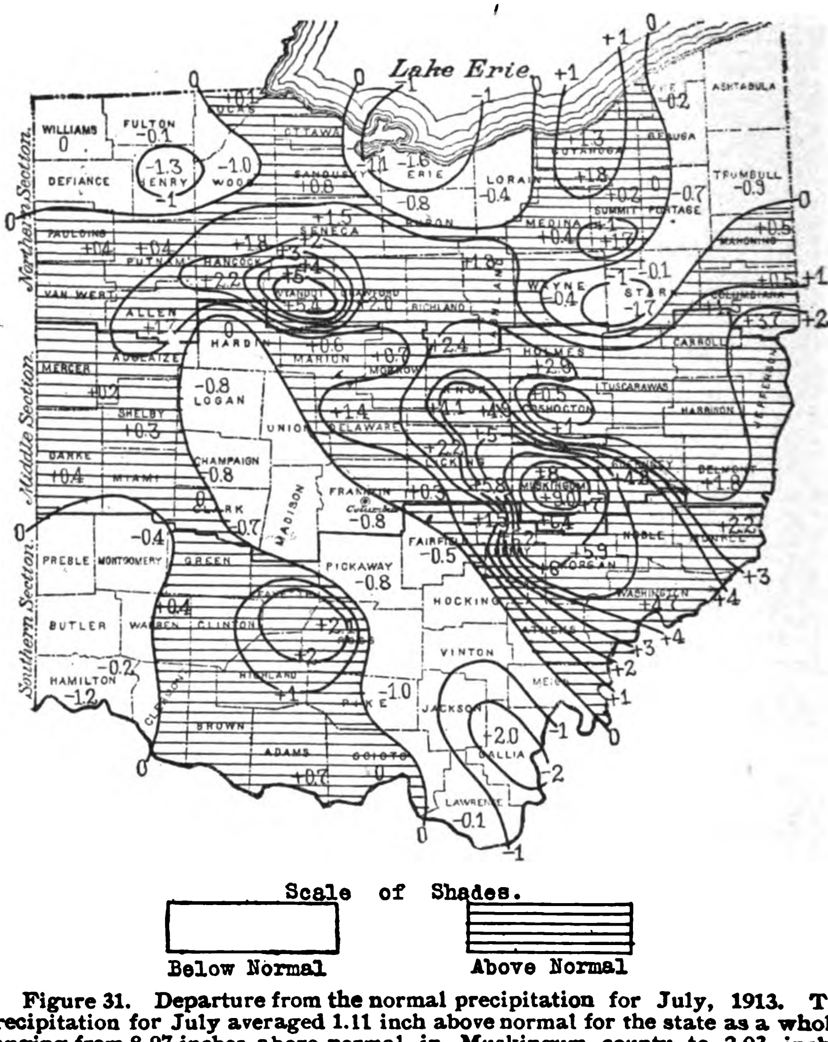


Figure 31. Departure from the normal precipitation for July, 1913. The precipitation for July averaged 1.11 inch above normal for the state as a whole, ranging from 8.97 inches above normal in Muskingum county to 2.03 inches below normal in Gallia county. The rainfall was mostly local, being excessive in a great many instances. The number of rainy days averaged 11.

Mean temperature, August, 1913

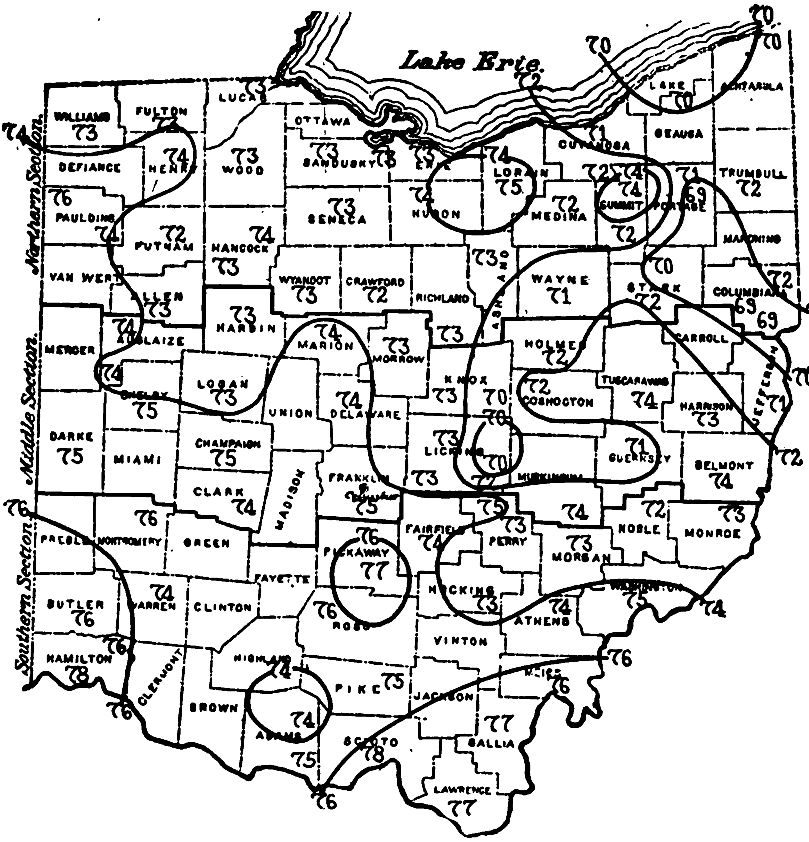


Figure 32. Average temperature. The average temperature for the state as a whole was 73.3°. The highest temperature reported during the month was 102° at Clarington, Monroe county, on the 9th, and the lowest was 39° at Garrettsville, Portage county, and New Waterford, Columbiana county, on the 25th.

Warm weather prevailed during the most of the period from the 7th to the 20th, inclusive, and on the 28th. On the 9th, 16th, 17th, 18th and 28th the afternoon temperatures reached close to the 100° mark in nearly all counties away from the influence of Lake Erie. Rather cool weather was experienced on the 4th, 5th, 24th, 25th, 30th and 31st.

Temperature departures, August, 1913

Figure 33. Temperature departures. The mean temperatures for the stations in the state averaged 2.0° above the normal. The greatest excess in temperature occurred in southern and western counties and the least in the eastern counties.

Precipitation, August, 1913

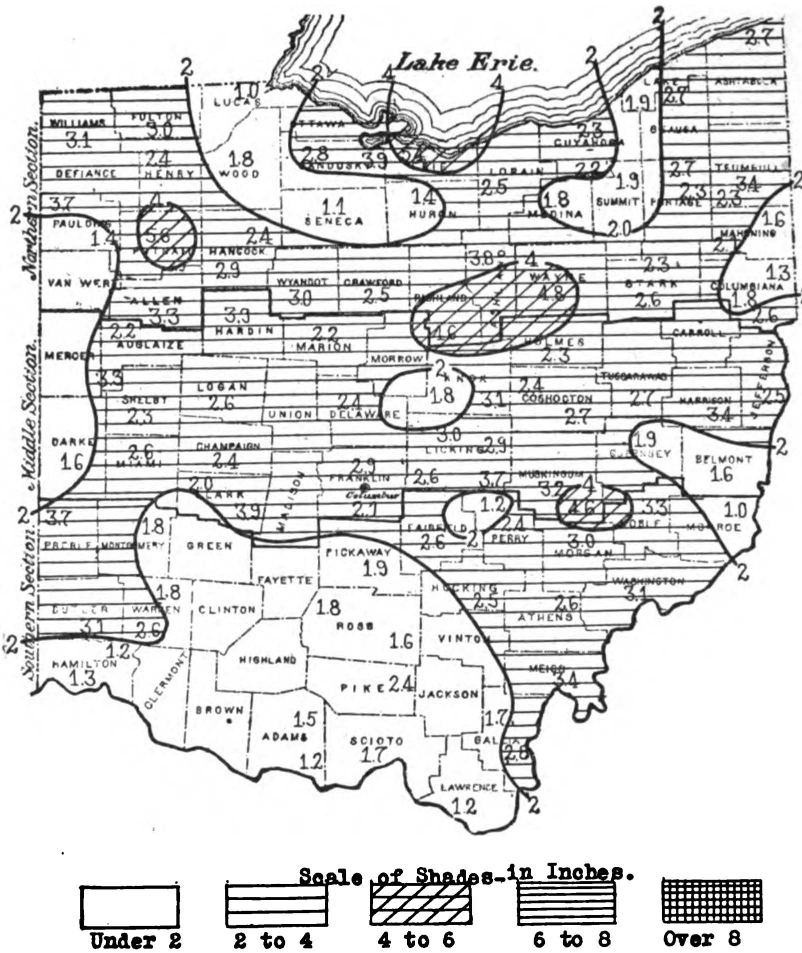


Figure 34. Precipitation for August, 1913. The average precipitation for the state as a whole was 2.52 inches. In general the greatest amount of rainfall occurred in the Muskingum and middle Maumee watersheds, and the least amount in several areas around the border of the state. The greatest amount recorded at one station was 5.57 inches at Ottawa, Putnam county, where there was a fall of 3.47 inches within 24 hours on the 21st and 22nd, and the least was 0.96 inch at Toledo. With the exception of the 21st and 22nd, the rains were generally scattered and light.

Precipitation departures, August, 1913

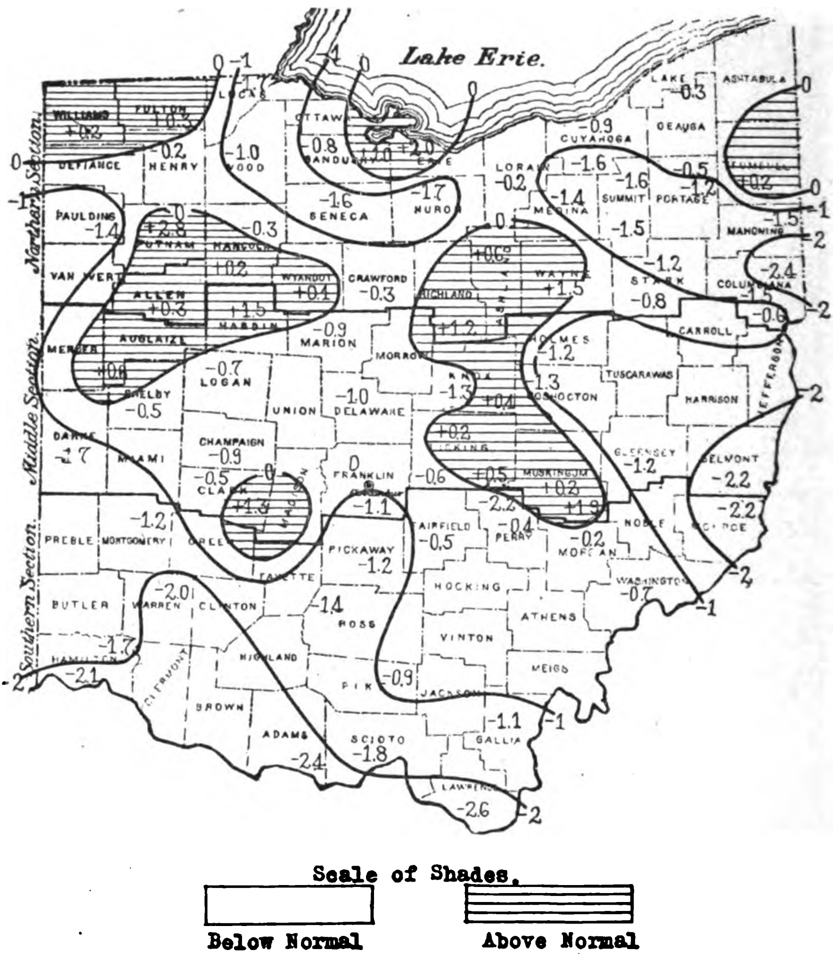


Figure 35. Precipitation departures for August, 1913. The precipitation averaged 0.64 inch below the normal amount for that month. More than the normal amount fell in a number of northern and middle counties, but in the southern counties there was a general deficiency. There was an average of only 6 rainy days during the month.

Mean temperature, September, 1913

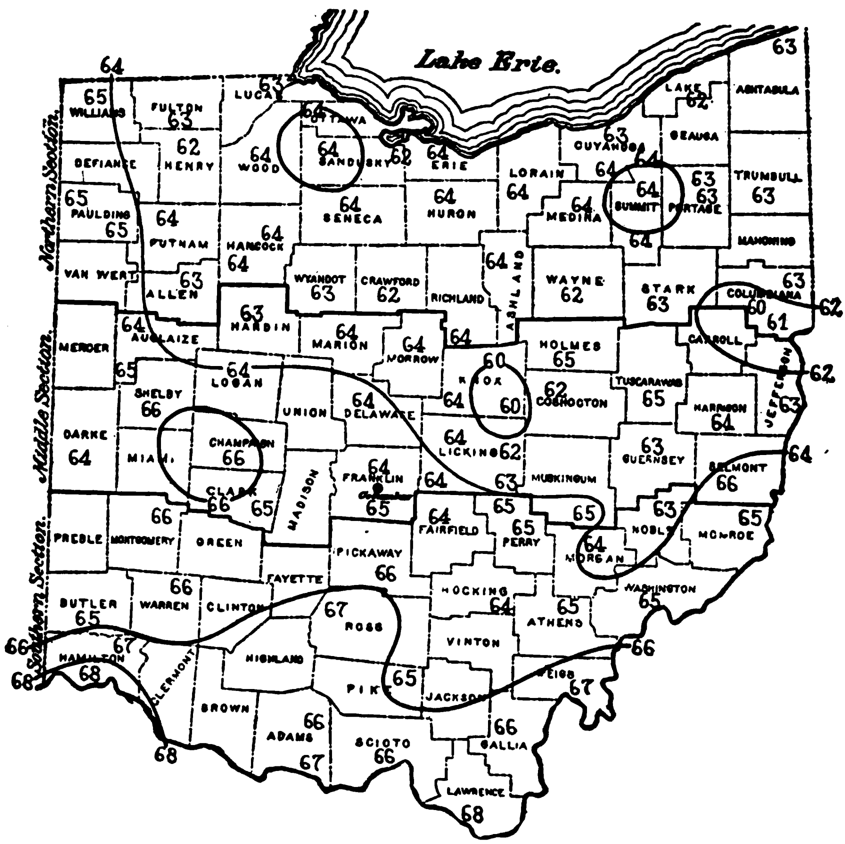


Figure 36. Average temperature for September, 1913. The average temperature for the state as a whole was 64.1°. The highest temperature reported during the month was 102° at Hamilton on the 2nd, and the lowest was 26° at Green Hill and Toboso on the 23rd.

The month was characterized by unusual temperature extremes. The first 7 days were exceptionally hot and the 23rd was exceptionally cold. All previous high temperature records for September were broken during the first 3 days at 9 stations and equalled at 9 others, and the low temperature records for September were broken at 6 stations and equalled at 11 others, on the 23rd. From the 9th to the 28th, inclusive, the temperatures were generally below normal. Frost and freezing temperatures were general, except along the lake shore and the Ohio river on the 23rd. Frost occurred also quite generally on the 14th, and in scattered localities on the 10th, 11th, 27th and 28th.

Temperature departures, September, 1913

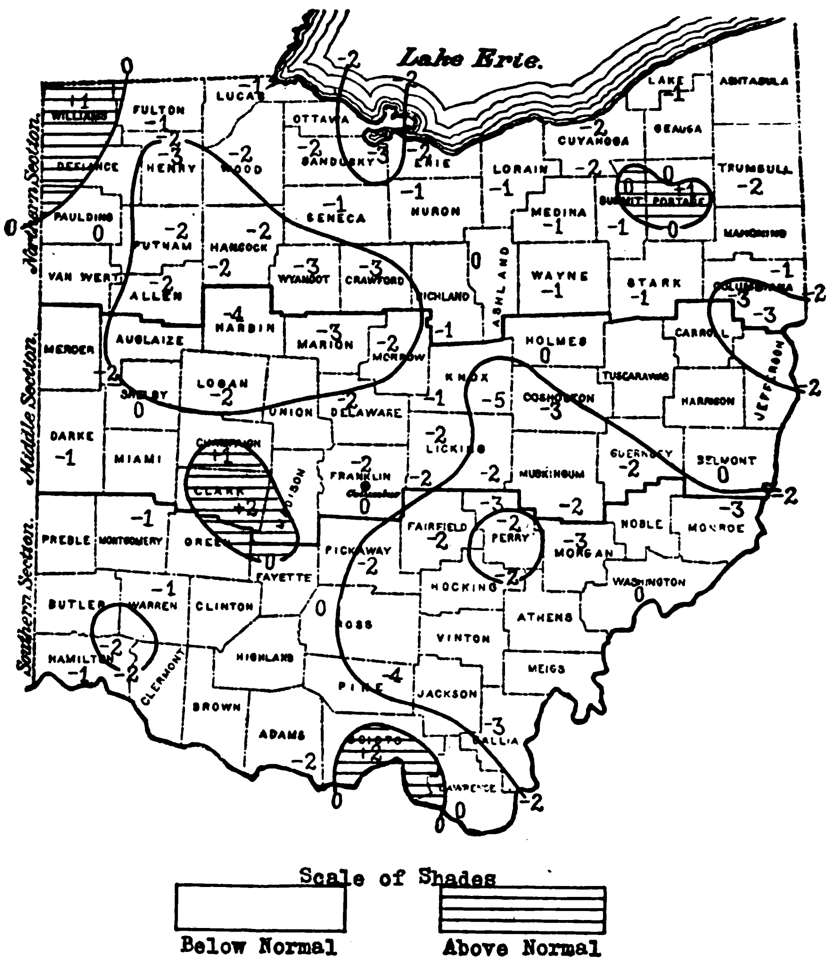


Figure 37. Temperature departures for September, 1913. The mean temperature for the stations in the state averaged 1.5° below the normal. It was below normal at practically all stations.

Precipitation, September, 1913

Figure 38. Rainfall for September, 1913. The average amount of rainfall for the state was 2.37 inches. The greatest amount fell in Stark and Tuscarawas counties and the least in Ashtabula county.

There was but little rainfall during the hot weather of the first week and the droughty conditions became quite serious in some localities. Light rains fell on the 7th, 8th and 12th, and during the 3rd week there was rain almost every day, and the drought was broken in all parts of the state. The last week was generally fair and cool, except on the 29th and 30th when light rains fell. Traces of snow were reported on the 22nd in Ashland, Auglaize and Knox counties.

Precipitation departures, September, 1913

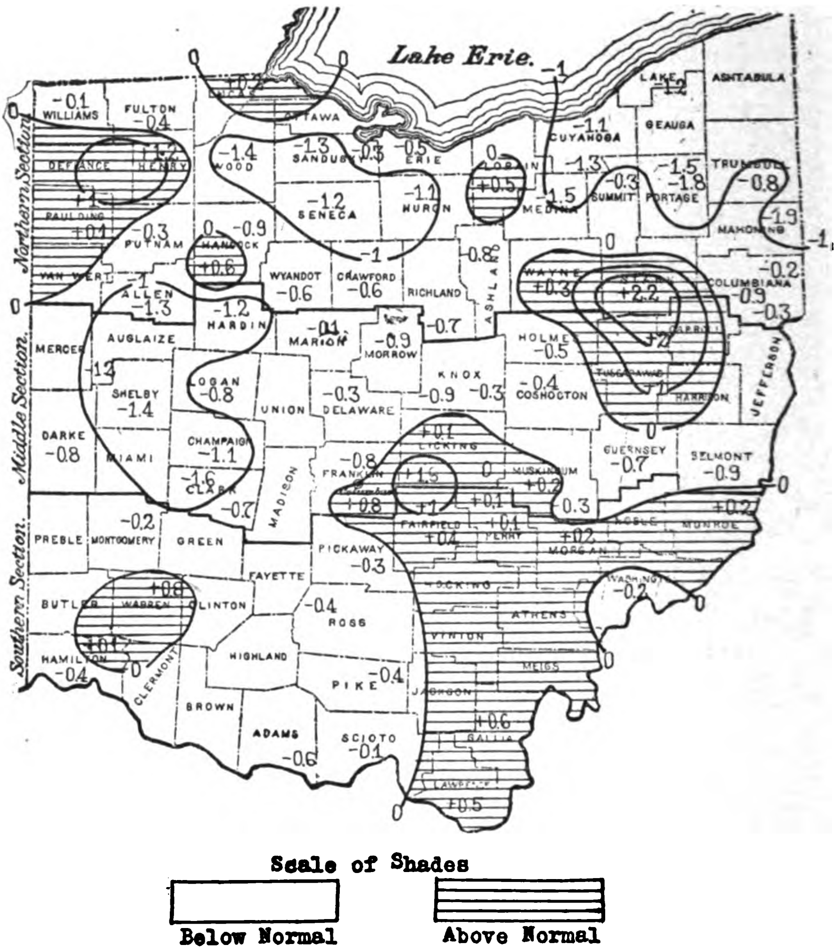


Figure 39. Precipitation departures for September, 1913. The rainfall averaged 0.41 inch below the normal amount for that month. More than the normal amount of rain fell in the southeastern counties, the Tuscarawas valley, and parts of the Maumee and Little Miami valleys. There was an average of 9 rainy days.

Mean temperature, October, 1913

Figure 40. Average temperature for October, 1913. The average temperature for the state as a whole was 54.1°. The highest temperature for the month was 96° at Demos, Belmont county, on the 7th, and the lowest was 18° at Milligan, Perry county, on the 22nd.

The weather was generally warm and pleasant during the first 17 days and cold, wet and disagreeable the remainder of the month. It was unusually warm from the 6th to the 10th, inclusive, the temperature reaching 90° at a number of stations. The coldest periods were the 19th-22nd and 30th-31st. On the 22nd the temperature fell considerably below the freezing point in all parts of the state, bringing the crop season to a close.

Temperature departures, October, 1913

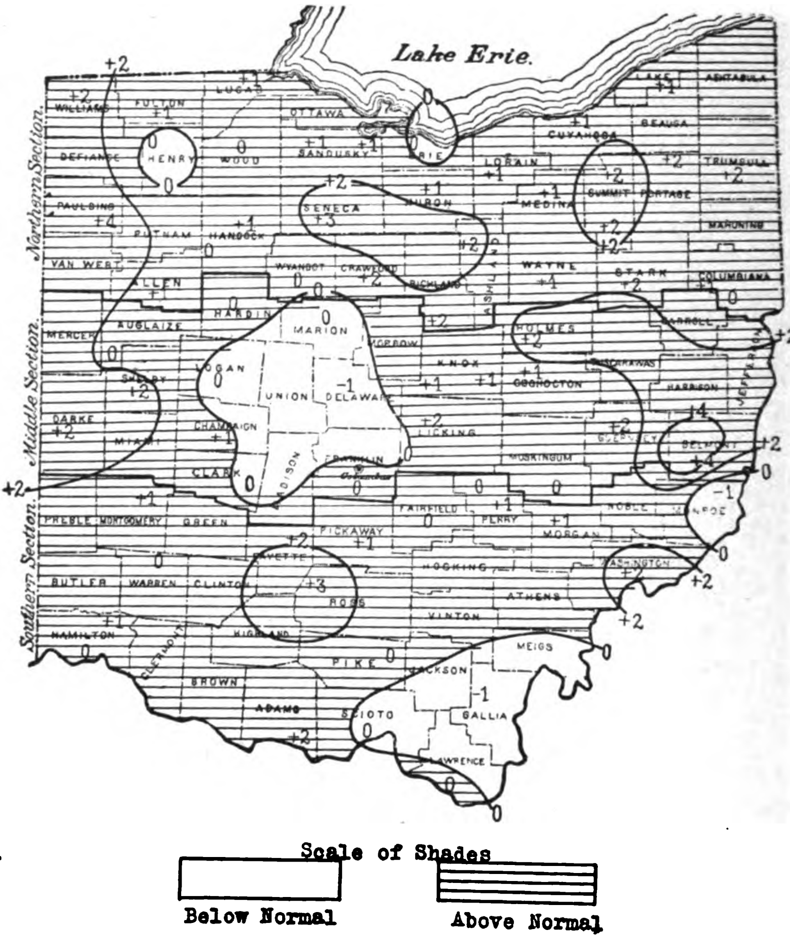


Figure 41. Temperature departures for October, 1913. The average temperature for the state was 1.1° above the normal. The greatest excesses in temperature occurred in northern and eastern counties and the greatest deficiencies occurred in some of the middle and southern counties.

Precipitation, October, 1913

Figure 42. Precipitation for October, 1913. The average precipitation for the state as a whole was 3.36 inches. It was heaviest in northern and extreme eastern counties and lightest in the lower Scioto valley. The monthly totals ranged from 6.51 inches in Lake county to 1.43 inch in Ross county. There were but two rainy periods during the first half of the month and they occurred on the 1st and 2nd, and 11th and 12th. But during the last two weeks rain fell in some part of the state on every day. The average number of rainy days was 12, clear days 10, partly cloudy days 7, and cloudy days 14.

Precipitation departures, October, 1913

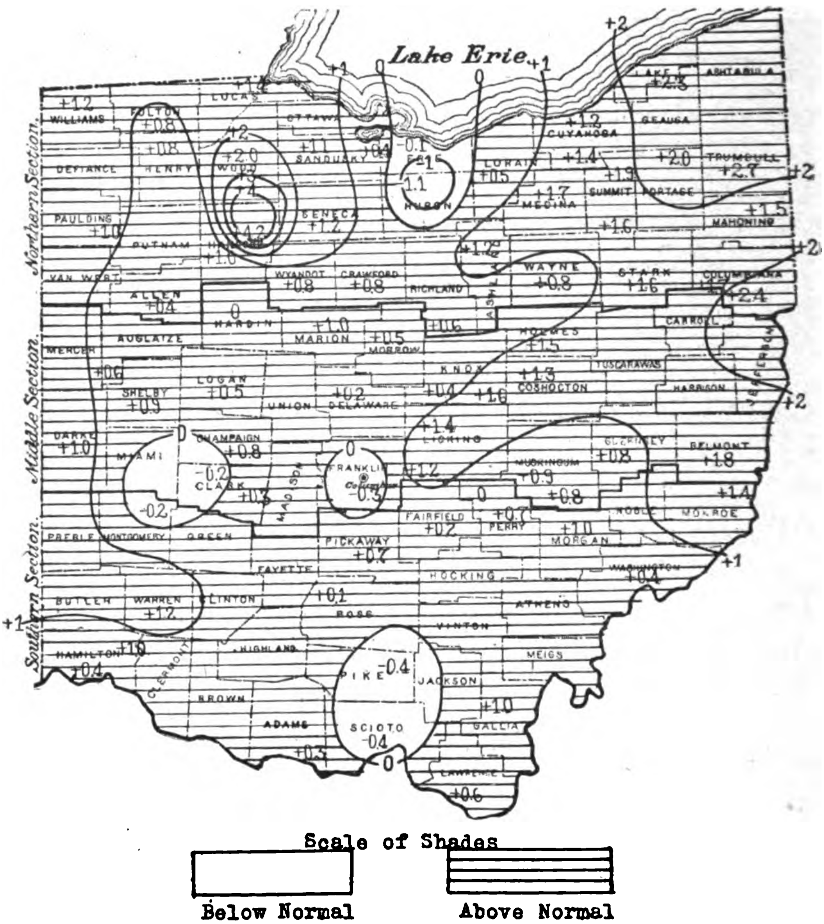


Figure 43. Precipitation departures for October, 1913. The average amount of precipitation for the state was 0.95 inch above the normal. It was above normal at nearly all stations. The greatest excess was 4.2 inches at Findlay and the greatest deficiency was 1.1 inch at Norwalk.

Snowfall, October, 1913

Figure 44. Snowfall for October, 1913. The average snowfall for the state was 0.3 inch. It ranged in amounts from 6.0 inches in Lake county to only flurries in some of the southern counties. Snow fell in the state on the 21st, 22nd, 28th, 30th and 31st.

Mean temperature, November, 1913

Figure 45. Average temperature for November, 1913. This was one of the warmest Novembers in Ohio of which there is record. The mean temperature for the state as a whole was 44.4°. The month opened cool, and with the exception of the 6th and 7th, the temperature was below normal continuously until the 13th. The temperature was above normal continuously during the last 13 days, and during a part of this time it was unseasonably high. The 20th and 22nd were among the warmest November days in Ohio of which there is record. The mean temperature for the 22nd was 29° above the normal at Toledo, 28° above at Cleveland, 25° above at Columbus and 26° above at Cincinnati. The lowest temperature for the month at most stations occurred on the 12th. It was unusually cold on that date for so early in the month, especially in the Muskingum valley, where at 2 stations it fell to 2° above zero.

Temperature departures, November, 1913

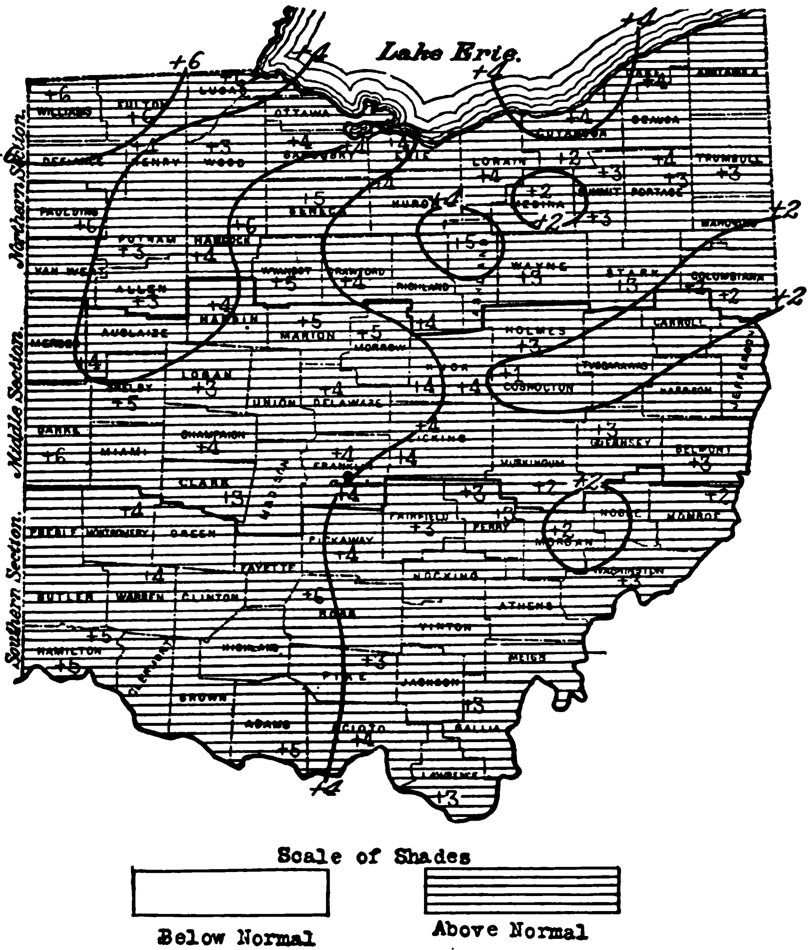


Figure 46. Temperature departures for November, 1913. The temperature for the state averaged 3.7° above normal. In general the greatest excess in temperature occurred along the western border and the least in the middle-eastern counties.

Precipitation, November, 1913

Figure 47. Precipitation for November, 1913. The average amount of precipitation for the state as a whole was 3.52 inches. It was heaviest in the southern counties and lightest in a few of the extreme eastern counties and middle-western counties. The monthly totals ranged from 5.21 inches in Harrison county to 1.66 inch in Mahoning county. There was much cloudiness, and precipitation occurred frequently during the last three weeks, especially in the southern districts. The average number of rainy days was 11; clear days, 10; partly cloudy days, 6; cloudy days, 14. Dense fog prevailed on the 27th, 28th and 29th.

Precipitation departures, November, 1913

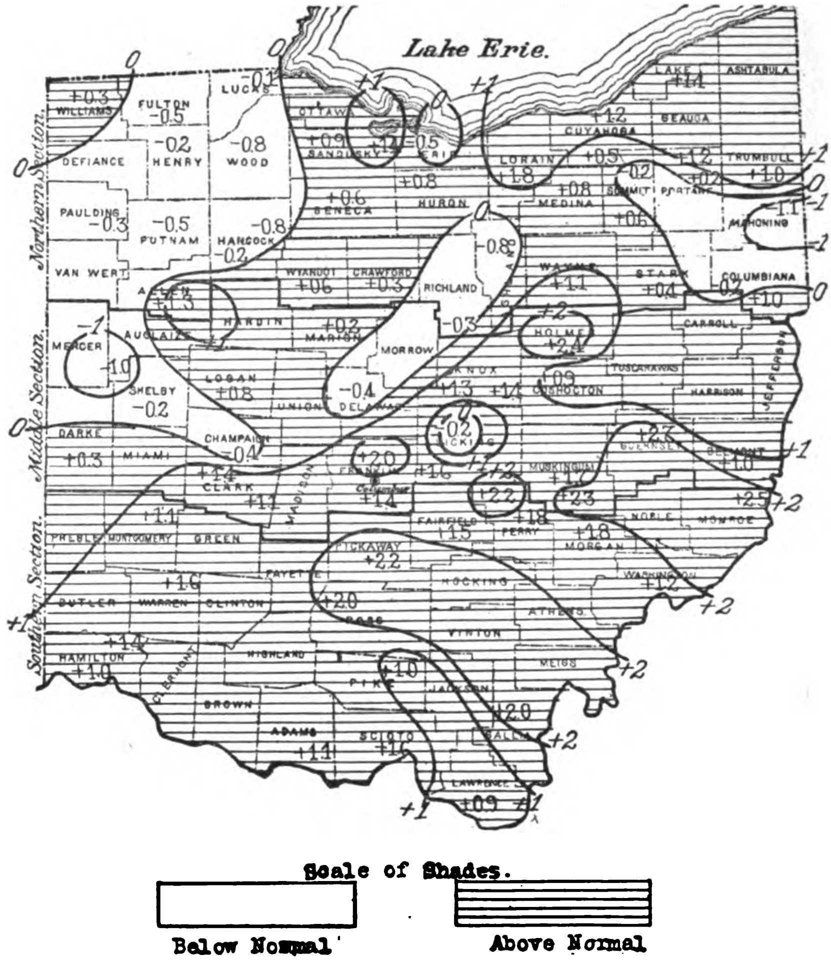
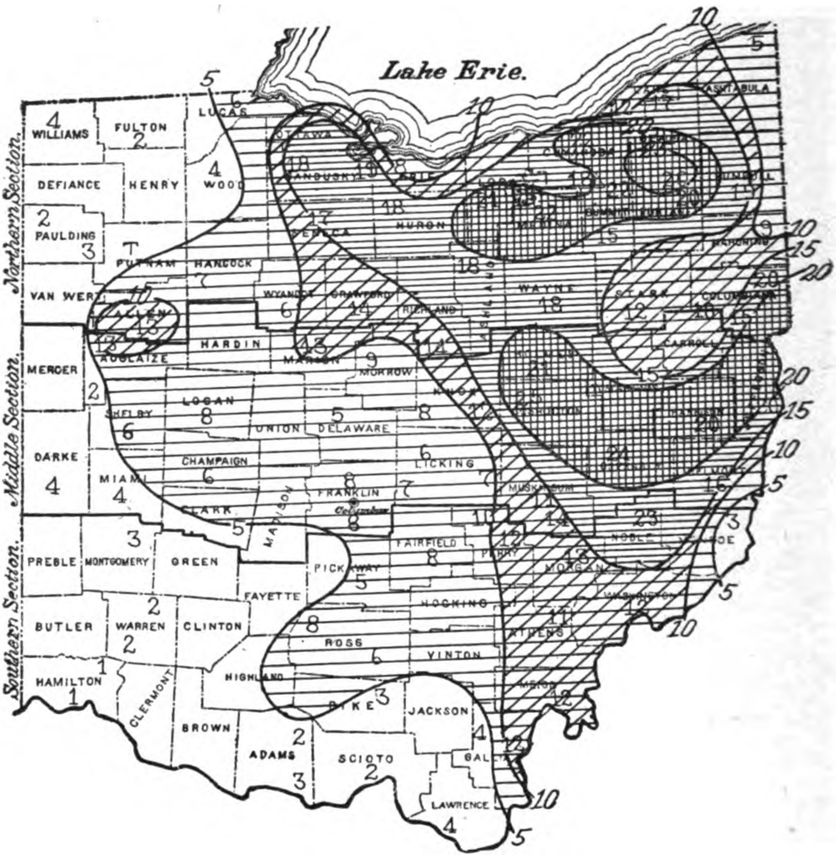


Figure 48. Precipitation departures for November, 1913. The average amount of precipitation for the state was 0.83 inch above normal. The greatest excess was 2.7 inches at Cambridge, Guernsey county, and the greatest deficiency was 1.1 inch at Youngstown, Mahoning county.

Snowfall, November, 1913



Scale of Shades—in Inches

Below 5 | 5 to 10 | 10 to 15 | 15 to 20 | Over 20

Figure 49. Snowfall for November, 1913. The snowfall was greater than for any other November of which there is record in Ohio. The average for the state was 10.8 inches. It practically all fell during the great snowstorm of the 9th and 10th. In parts of the Cuyahoga and Muskingum valleys the total fall was about 25 inches. It gradually decreased towards the west and in Hamilton county it was only about one inch.

Mean temperature, December, 1913

Figure 50. Average temperature for December, 1913. The month was considerably warmer than usual. The mean temperature for the state as a whole was 34.5°. The temperature was generally above normal during the first 6 days and from the 12th to the 24th, inclusive. It was much above normal on the first 4 days and on the 12th, 13th and 14th. Moderately cold weather was experienced on the 8th and 9th and during the last week; but there were no extremely cold days. The temperature fell to slightly below zero at several places in eastern Ohio on the 28th. There were no sudden temperature changes of importance during the month and the daily changes in temperature were exceptionally small.

Temperature departures, December, 1913

Figure 51. Temperature departures for December, 1913. The temperature for the state as a whole averaged 3.7° above the normal. In general the greatest excess in temperature occurred in northern and western counties, so that the mean temperatures for the stations in the northern part of the state were nearly as high as for those in the extreme southern counties.

Precipitation, December, 1913

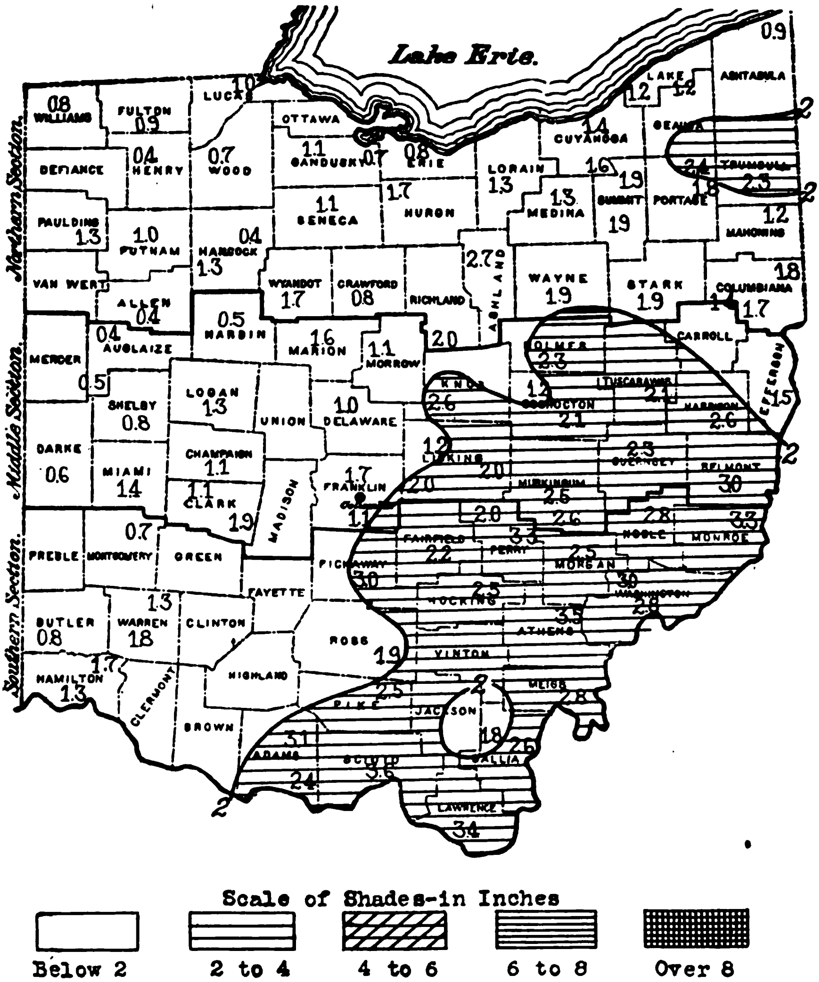


Figure 52. Precipitation for December, 1913. The average amount of precipitation for the state as a whole was 1.68 inch. In general the precipitation was heaviest in the extreme southern and southeastern counties and lightest in the middle western counties. There were no heavy rains during the month and the number of days on which precipitation occurred were fewer than usual.

Precipitation departures, December, 1913

Scale of Shades

Below Normal — Above Normal

Figure 53. Precipitation departures for December, 1913. The average amount of precipitation for the state was 1.16 inch below the normal. The precipitation was deficient at nearly all reporting stations. The greatest excess was 0.6 inch at Circleville, Pickaway county, and Ironton, Lawrence county. The greatest deficiency was 2.7 inches at Lima, Allen county.

Snowfall, December, 1913

Scale of Shades-in Inches

Below 5 | 5 to 10 | 10 to 15 | 15 to 20 | Over 20

Figure 54. Snowfall for December, 1913. There was less snowfall than usual in nearly all counties. The monthly totals ranged from 15 inches in Portage county to only traces in some of the extreme southern counties. The average for the state as a whole was 3.7 inches. Most of the snow fell on the 7th, 8th, 25th and 26th.

CLIMATOLOGICAL DATA FOR OHIO FOR THE YEAR 1913.

	Monthly mean	Departure from normal	Highest	Date	Lowest	Date	Range	Greatest daily range	Average precipitation	Departure from normal	Average snowfall	Number of rainy days	Number of clear days	Number of partly cloudy days	Number of cloudy days
January	36.0	+7.8	70	20*	3	9	67	42	7.01	+4.17	8.6	17	7	6	18
February	26.7	−0.5	77	21	−15	6	91	50	1.94	−0.77	6.9	8	12	6	10
March	40.1	+0.9	80	14	−8	8	88	58	8.40	+5.28	5.1	13	11	9	11
April	50.0	+0.6	90	25	18	21	72	52	3.35	+0.30	T	10	14	6	10
May	60.3	−0.6	95	4	23	11*	72	54	3.53	−0.12	0	10	14	8	9
June	69.8	+0.6	105	30	29	10	76	48	1.87	−2.04	0	6	20	7	3
July	74.5	+1.0	103	29*	40	11	63	44	5.20	+1.11	0	11	16	12	3
August	73.3	+2.0	102	9	39	25	63	48	2.52	−0.64	0	6	17	10	4
September	64.1	−1.5	102	2	26	23	76	50	2.37	−0.41	T	9	14	7	9
October	54.1	+1.1	96	7	18	22	78	51	3.36	+0.95	0.3	12	10	7	14
November	44.4	+3.7	78	7*	2	12	76	51	3.52	+0.83	10.8	11	10	6	14
December	34.5	+3.7	65	2*	−3	28	67	38	1.68	−1.16	3.7	7	8	6	17

*On other dates also.

METEOROLOGICAL SUMMARY FOR 1913

By C. A. PATTON

EXPLANATION OF TABLES

The following tables contain statistics of temperature, rainfall, etc., for the year, and are compiled from data obtained from daily observations. T stands for "trace"—less than .01 inch of rainfall. Temperature is given in degrees Fahrenheit.

Table I shows the daily rainfall at the Experiment Station at Wooster during the year in inches and hundredths.

Table II shows the daily mean temperature for each day of 1913 and the monthly mean temperature with the 26 years' average.

Table III gives the monthly mean temperature at the station with the 26 years' average for the same.

Table IV gives the monthly mean rainfall at the station with the 26 years' average for the same.

Table V gives the monthly mean temperature for the state for 1913 with 26 years' average.

Table VI gives the monthly mean rainfall for 1913 with the 26 years' average for the state.

Table VII gives the monthly mean temperature and rainfall for the station and state for 1913 with the 26 years' average.

Table VIII contains the mean temperature, the highest and lowest temperatures with the range of temperature for each month; the number of clear, partly cloudy and cloudy days; the rainfall, snowfall and prevailing direction of wind, for both the station and state for 1913.

Table IX contains the principal points of interest on temperature, rainfall, and state of weather at the station during the year, and a grand summary for 26 years.

Table X contains the principal points of interest on temperature, rainfall, and state of weather for the state during the year and a grand summary for 31 years.

Table XI gives the highest and lowest temperature for each month during the past 26 years for both the station and state.

Table XII gives the total and average precipitation at the different district test farms.

Some slight errors in previous publications of tables five, nine and eleven are corrected in this report.

NOTES ON THE WEATHER AT WOOSTER 1913
SUMMARY BY MONTHS

LATITUDE 40° 47′ 01″, LONGITUDE 81° 55′ 48″
ELEVATION ABOVE SEA LEVEL 1,030 FEET

JANUARY

The mean temperature was 34.2° this being 6.6° above the average for this month. The precipitation was more than double the average amount for January, being 7.86 inches. The highest temperature recorded was 57° on the 20th and the lowest was 4° on the 5th. Two heavy snows during the month, both melting off in a few days.

FEBRUARY

The mean temperature was 25.1° which is 1.3° below the average for February. The highest temperature 62° occurred on the 19th. The lowest —2° on the 6th. The precipitation was 2.43 inches, which is slightly below the average for this month. The snowfall for the month amounted to 11.50 inches.

MARCH

The mean temperature for March was above the average, a very severe windstorm on the 21st lasting all day, doing much damage to roofs, fences, etc. Followed on the 23rd by the beginning of the most destructive flood in the history of the county. The rainfall in five days amounting to 10.15 inches. The total precipitation for the month was 11.84 inches, which is 8.10 inches above the average for March.

APRIL

The mean temperature was 48.9 which is slightly above the average for April. The highest temperature 83° occurred on the 25th, the lowest 20° on the 21st. The rainfall was 3.66 inches. This is .65 inch above the average for April. The prevailing wind was from the northwest.

MAY

The mean temperature for May was 58.0, which is 6° below the average for this month. The highest temperature recorded was 86° on the 5th and the lowest was 25° on the 11th. The rainfall was almost one inch below the average.

JUNE

The mean temperature was 67.4°, this is mean for the past twenty-six years for June. Very cold north winds on the 8th and 9th followed by a killing frost on the 10th, doing much damage to corn and early garden truck on low lands. The rainfall was far below the average, being only .97 inch.

JULY

The mean temperature for the month was 72.4° which is 1.° above the average for this month. The rainfall was 4.07 inches, which is very slightly below the average for July. The month was noted for its many extremely warm days, and numerous electrical storms, some rain falling on sixteen days.

AUGUST

The mean temperature for August was 71.5° degrees which is 2.1° above the average. The highest temperature recorded was 96° on the 17th. The lowest was 45° on the 25th. The rainfall was 1.19 inch above the average. The total fall was 4.75 inches.

SEPTEMBER

The mean temperature for September was below the average, the highest 93°, occurred on the 2nd and 3rd, the lowest 28°, on the 23rd. A light frost on the 14th injuring tender plants and vegetation. A killing frost on the 23rd. The total rainfall was 3.70 inches which is .35 inch above the average for September.

OCTOBER

The weather for the first half of October was very fine. The mean temperature was 1° above the average for the month. The total rainfall was 3.17 inches. The highest temperature recorded was 81° on the 6th, 9th and 10th. The lowest 24° occurred on the 22nd.

NOVEMBER

The mean temperature for November was 2.4° above the average for the month. The highest 73° occurred on the 22nd and the lowest 12° on the 12th. A terrific snow blizzard from the northwest and lasting two days and nights without ceasing occurred on the 9th and 10th. The total fall was estimated at 18 inches, drifting to a depth of six or eight feet in places. Roads were impassible for several days. The total precipitation was 3.77 inches.

DECEMBER

The mean temperature was 33.7 which is 3° above the average for December. The highest temperature recorded was 56° on the 2nd. The lowest 7°, on the 28th. The total precipitation was 1.92 inches, which is below the average for this month.

METEOROLOGY—TABLE I—RAINFALL

DAILY RAINFALL AND MELTED SNOW FOR 1913 AT THE EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1	....	....	.20	....	...	.18	.42	....	....	.40	....	.32	1
2	....	....	...	1.04	....	..	.03	....	....	.48	....	....	2
3	.50	.40	....	.04	....	T	....	....	....	.14	....	.02	3
4	.20	....	.35	.60	....	.05	....	.18	T	....	....	....	4
5	.20	....	.07	T	....	....	.50	....	....	....	....	....	5
6	.10	....	.20	....	T	....	.30	....	....	....	....	.05	6
7	.86	....	....	....	....	.02	....	....	T	....	.05	.30	7
8	.52	....	....	....	....	....	....	.06	.03	....	.63	.20	8
9	....	....	T	T	.02	...	.02	....	...	....	1.00	....	9
10	.09	....	T	.24	....	....	....	.45	....	....	.80	T	10
11	.83	T	.10	.17	....	....	....	....	....	.37	T	....	11
12	.40	T	....	....	....	....	.30	.50	....	.03	....	....	12
13	....	....	....	.31	....	....	.58	....	....	....	.50	....	13
14	....	....	....	T	....	....	.39	....	...	....	.40	....	14
15	.02	....	....	.01	.57	....	.04	....	....	....	.03	....	15
16	.62	....	.05	....	....	....	....	....	.18	....	.04	....	16
17	.75	.40	.05	....	....	....	.05	....	2.20	.20	....	....	17
18	.23	....	....	....	....	....	....	1.65	.29	.02	.05	T	18
19	....	....	....	....	....	....	.01	....	....	.15	T	....	19
20	.80	....	....	....	...	.65	.20	....	.60	.26	....	....	20
21	.07	....	.40	....	.10	.05	...	1.35	T	.02	....	.18	21
22	....	.23	....	....	.15	....	....	.50	.12	.06	....	....	22
23	.80	....	1.16	....	.03	....	.20	....	....	T	....	.45	23
24	....	.05	1.94	....	....	....	.07	....	....	.81	....	....	24
25	....	....	4.84	....	....	.02	....	....	....	....	....	.10	25
26	....	.35	1.40	.47	.70	....	...	....	.02	....	.07	.30	26
27	....	.70	.81	.27	1.30	....	.84	....	....	....	T	....	27
28	.60	.30	....	.45	T	...	....	....	....	.05	.10	....	28
29	.02	....	....	.06	T	....	....	.06	.25	.10	.10	....	29
30	....	...	....	....	.17	....	.12	....	.01	.08	T	....	30
31	.25	....	.27	....	....	....	....	....	....	T	....	....	31
Total	7.86	2.43	11.84	3.66	3.04	.97	4.07	4.75	3.70	3.17	3.77	1.92	
Average	.254	.087	.382	.122	.098	.032	.131	.153	.123	.102	.126	.062	

METEOROLOGY—TABLE II—TEMPERATURE

MEAN TEMPERATURE FOR EACH DAY OF 1913, AT THE EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1	31.5	14.0	26.0	45.0	57.5	64.5	81.5	75.5	72.5	63.0	33.0	51.0	1
2	39.0	14.5	15.5	42.5	50.0	61.5	76.5	68.5	75.5	55.0	35.0	50.5	2
3	34.0	26.0	27.5	52.5	76.0	63.0	75.5	71.5	76.5	53.5	42.0	46.5	3
4	22.0	18.0	33.5	56.5	67.0	61.0	86.5	70.5	75.0	55.0	45.0	42.0	4
5	17.0	10.0	21.5	41.0	68.0	57.0	76.0	64.5	74.0	59.0	40.5	43.0	5
6	39.0	6.5	20.5	38.5	67.0	67.5	70.0	67.5	75.5	66.0	44.0	39.0	6
7	35.5	13.0	11.0	33.0	50.0	66.0	60.5	74.0	77.0	64.5	53.5	36.5	7
8	36.5	18.5	28.5	35.5	50.5	50.5	66.0	72.0	71.0	66.5	47.0	23.0	8
9	20.5	20.0	47.5	41.0	52.0	47.5	72.5	80.5	58.5	68.5	32.5	23.0	9
10	28.0	18.0	39.0	49.0	40.5	49.5	67.5	83.0	58.0	68.5	23.5	30.0	10
11	43.0	24.5	38.5	53.0	40.0	54.0	62.0	71.5	60.0	60.5	25.5	31.0	11
12	35.5	14.5	41.5	43.0	46.0	58.0	75.5	69.5	59.5	48.5	27.5	36.0	12
13	23.0	12.0	54.5	42.5	62.0	62.0	76.5	72.5	53.0	45.5	46.0	42.5	13
14	27.5	24.5	64.0	47.0	58.0	66.0	73.0	73.0	50.0	48.5	42.0	41.5	14
15	35.5	33.5	52.5	48.5	56.0	70.5	70.5	78.5	56.5	56.5	30.5	32.5	15
16	44.0	32.5	28.5	50.0	65.0	80.5	68.0	78.0	61.0	61.0	36.5	38.5	16
17	50.0	30.0	26.0	51.0	60.0	75.0	77.0	80.5	66.0	58.0	30.5	37.0	17
18	42.5	27.0	44.0	63.0	64.0	68.5	75.0	79.0	61.5	53.0	44.5	32.5	18
19	35.5	46.5	53.0	55.5	52.0	72.5	72.0	74.0	59.5	43.0	55.5	28.5	19
20	45.0	48.5	59.5	37.0	56.0	76.0	68.0	72.5	64.5	40.0	58.5	31.0	20
21	26.5	44.5	51.5	40.0	67.0	74.0	65.5	73.0	54.5	36.0	58.0	33.0	21
22	29.5	44.5	31.0	60.5	64.5	62.0	66.0	72.0	45.5	35.5	63.0	28.5	22
23	42.5	28.5	37.5	70.0	54.5	65.0	70.5	64.0	45.0	54.5	54.0	31.0	23
24	41.0	18.0	49.5	60.0	55.0	74.5	71.5	63.0	58.0	51.0	40.5	36.0	24
25	35.5	26.0	49.5	64.0	55.5	78.5	62.5	60.5	62.5	50.0	34.5	33.0	25
26	43.0	28.5	45.5	62.0	51.0	81.0	68.5	69.0	62.5	52.0	41.5	29.0	26
27	37.0	33.5	28.5	47.0	58.0	80.5	74.5	68.0	51.0	46.5	43.5	20.5	27
28	25.0	27.5	26.0	42.0	61.0	80.0	80.0	69.0	54.0	43.0	44.5	18.5	28
29	26.0	....	42.5	47.5	60.5	74.5	78.0	72.0	65.0	44.0	47.5	27.0	29
30	37.0	....	52.0	48.0	65.5	82.0	80.5	62.0	71.0	37.5	52.0	25.0	30
31	34.0	....	48.5	....	58.5	....	77.0	66.0	....	34.5	....	29.0	31
Monthly mean	34.2	25.1	38.5	48.9	58.0	67.4	72.4	71.5	62.5	52.2	42.4	33.7	
26-yr. average	27.6	26.4	37.3	48.1	58.6	67.4	71.4	69.4	64.0	51.2	40.0	30.6	

METEOROLOGY—TABLE III

MONTHLY MEAN TEMPERATURE FOR TWENTY-SIX YEARS AT WOOSTER

Temperature in degrees Fahrenheit

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888..........	23.0	28.8	31.7	46.3	57.7	68.9	70.1	67.8	57.1	44.9	40.7	31.4	47.4	1888
1889..........	31.1	22.9	38.7	47.1	57.8	64.5	70.0	66.0	60.8	45.3	39.3	40.7	48.6	1889
1890..........	36.0	36.6	30.9	48.4	56.0	69.8	70.5	65.8	59.6	50.0	41.3	28.8	49.5	1890
1891..........	30.0	34.0	32.0	49.0	52.0	68.0	68.0	71.0	68.0	49.0	38.0	37.0	49.7	1891
1892..........	22.0	33.0	33.0	47.0	57.0	70.0	70.0	69.0	61.0	49.0	38.0	28.0	48.0	1892
1893..........	18.0	28.0	38.8	50.1	57.6	69.3	72.0	67.9	63.2	52.3	37.7	30.9	48.7	1893
1894..........	32.8	26.7	43.5	50.5	57.5	67.9	71.4	69.2	66.1	52.3	36.5	32.9	50.6	1894
1895..........	21.9	17.9	32.4	49.5	59.4	69.9	68.6	70.9	66.5	44.2	40.4	32.8	47.8	1895
1896..........	27.9	29.2	29.8	54.6	64.5	65.6	70.2	68.5	60.6	45.8	44.4	30.6	49.3	1896
1897..........	24.0	30.0	39.3	47.2	53.4	64.3	73.2	67.0	66.7	55.9	40.7	31.8	49.4	1897
1898..........	31.6	27.4	43.3	45.3	58.2	68.7	74.5	71.1	66.2	52.6	38.4	27.9	50.4	1898
1899..........	26.6	21.3	35.0	52.1	60.0	69.4	70.0	71.0	61.6	55.0	43.2	29.0	49.5	1899
1900..........	30.2	25.0	31.8	47.8	61.5	68.5	72.6	74.0	67.1	58.9	40.6	30.7	50.7	1900
1901..........	28.3	20.0	39.1	45.2	57.9	69.1	75.9	71.6	63.3	51.7	36.6	26.1	48.7	1901
1902..........	26.3	21.4	41.2	46.2	61.2	65.6	73.0	66.4	62.7	53.9	47.3	28.7	49.5	1902
1903..........	24.4	29.0	45.7	48.0	62.2	63.0	71.8	68.8	64.4	58.2	36.8	21.7	49.1	1903
1904..........	18.6	20.5	37.6	42.8	59.4	67.0	69.8	66.7	64.2	50.4	39.6	28.1	47.1	1904
1905..........	22.6	19.8	41.2	46.8	59.2	68.0	71.6	70.0	63.8	51.0	38.3	33.1	48.8	1905
1906..........	35.9	25.8	30.2	51.9	59.9	68.8	71.0	74.2	67.7	51.4	40.4	31.2	50.7	1906
1907..........	30.8	24.6	44.9	41.7	52.8	64.6	69.9	68.6	65.0	47.4	38.5	32.1	48.4	1907
1908..........	28.7	26.8	43.1	50.1	62.2	68.1	72.4	69.0	66.4	53.0	41.0	31.7	51.0	1908
1909..........	31.7	33.6	35.9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	50.0	1909
1910..........	26.7	23.8	47.2	50.2	54.7	64.3	72.6	70.9	65.3	54.9	34.8	24.4	49.2	1910
1911..........	31.3	33.8	35.0	46.5	63.5	68.9	71.7	70.6	65.2	51.8	36.7	34.7	50.8	1911
1912..........	16.6	20.5	30.3	50.0	61.1	64.6	71.6	67.1	65.6	52.4	41.0	33.1	47.8	1912
1913..........	34.2	25.1	38.5	48.9	58.0	67.4	72.4	71.5	62.5	52.2	42.4	33.7	50.6	1913
26-yr. av...	27.6	26.4	37.3	48.1	58.6	67.4	71.4	69.4	64.0	51.2	40.0	30.6	49.3	

METEOROLOGY—TABLE IV

MONTHLY RAINFALL FOR TWENTY-SIX YEARS AT WOOSTER

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Date
1888........	3.34	2.43	3.34	2.48	3.82	2.31	4.54	4.35	1.92	3.18	4.95	1.39	38.05	1888
1889........	4.33	2.42	2.13	1.58	2.97	4.86	6.73	1.98	4.05	1.36	3.53	3.93	39.87	1889
1890........	4.71	6.20	4.37	3.10	6.37	4.92	2.67	4.66	5.13	7.45	2.62	1.74	53.94	1890
1891........	2.91	4.83	3.71	1.66	2.24	7.13	3.24	1.85	0.93	1.33	5.73	2.92	38.48	1891
1892........	2.67	2.67	3.38	2.44	7.69	7.89	4.73	2.69	3.20	0.37	2.06	2.74	41.53	1892
1893........	4.01	6.33	1.89	5.66	6.28	2.51	1.38	1.53	1.85	5.15	2.49	1.50	40.58	1893
1894........	2.19	3.37	2.36	1.74	4.41	2.23	1.38	0.76	4.25	2.53	2.41	3.15	30.78	1894
1895........	3.97	0.41	1.98	1.69	1.38	4.20	2.19	2.30	3.92	1.15	4.21	3.51	30.91	1895
1896........	1.73	2.27	3.67	3.34	3.41	3.98	8.05	1.96	5.16	0.71	1.78	3.04	39.10	1896
1897........	3.42	2.64	2.81	2.75	4.97	2.98	3.89	3.86	0.29	0.89	5.76	2.50	36.76	1897
1898........	4.10	2.27	6.44	2.56	4.60	2.70	6.79	5.53	2.15	4.28	4.14	2.29	47.85	1898
1899........	3.29	1.64	3.95	1.28	4.42	1.95	3.73	0.53	5.56	2.21	1.59	2.78	32.93	1899
1900........	2.78	2.74	2.25	1.70	2.23	3.71	5.65	5.97	2.19	2.10	4.30	0.99	36.61	1900
1901........	1.58	1.20	3.09	2.46	4.32	4.82	3.52	3.58	5.64	0.79	1.62	3.47	35.89	1901
1902........	0.63	0.83	2.99	1.55	2.57	5.55	5.26	1.87	3.49	1.52	2.62	4.07	32.95	1902
1903........	3.54	3.69	3.29	4.55	1.59	3.69	4.61	6.58	2.07	2.63	2.25	1.95	40.44	1903
1904........	5.27	3.90	6.22	6.59	4.45	1.67	4.93	2.03	2.27	0.87	0.40	2.68	41.28	1904
1905........	1.83	1.36	2.61	2.51	5.97	7.50	5.14	4.47	5.10	2.32	2.04	2.08	42.93	1905
1906........	1.93	1.06	3.57	2.27	2.98	3.81	4.93	7.38	5.16	3.55	2.39	3.79	42.82	1906
1907........	6.92	1.09	5.80	2.69	3.48	3.81	3.96	2.04	3.13	2.34	1.33	3.41	40.00	1907
1908........	1.96	3.89	5.02	3.64	4.56	2.17	3.44	3.17	0.73	1.22	1.09	3.05	33.94	1908
1909........	2.95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.91	2.55	44.22	1909
1910........	5.29	4.41	0.54	3.22	4.87	2.57	1.12	0.95	2.59	5.24	2.36	2.29	35.45	1910
1911........	4.13	2.25	3.26	3.71	2 45	3.78	3.36	5.19	6.53	5.45	2.50	4.54	47.15	1911
1912........	2.30	1.58	3.77	5.58	5.65	2.21	7.46	7.32	4.41	2.18	1.79	2.35	46.60	1912
1913........	7.86	2.43	11.84	3.66	3.04	0.97	4.07	4.75	3.70	3.17	3.77	1.92	51.18	1913
26-yr. av...	3.45	2.82	3.74	3.01	4.03	3.86	4.25	3.56	3.35	2.54	2.79	2.68	40.08	

METEOROLOGY—TABLE V

MONTHLY MEAN TEMPERATURE FOR TWENTY-SIX YEARS FOR THE STATE

Temperature in degrees Fahrenheit

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888........	24.3	30.5	34.2	49.2	58.8	70.4	72.1	70.4	60.3	47.9	42.9	33.3	49.5	1888
1889........	33.3	25.8	40.2	49.9	60.2	66.7	72.5	69.1	62.9	47.9	41.0	43.8	51.1	1889
1890........	38.8	39.4	34.5	51.3	59.2	73.3	73.0	68.8	62.1	52.7	42.2	31.2	52.2	1890
1891........	33.0	36.0	35.0	52.0	58.0	71.0	69.0	70.0	67.0	51.0	40.0	39.0	51.8	1891
1892........	24.0	35.0	35.0	49.0	59.0	73.0	73.0	71.0	64.0	52.0	38.0	29.0	50.2	1892
1893........	18.0	29.0	38.0	50.2	58.3	70.6	74.5	70.7	65.2	53.7	39.3	32.7	50.0	1893
1894........	33.7	28.9	45.1	50.6	60.0	71.3	74.3	71.2	67.8	53.9	37.5	33.9	52.4	1894
1895........	23.4	19.6	35.5	51.7	61.1	72.0	71.6	73.5	69.0	46.9	41.9	33.9	50.0	1895
1896........	29.4	30.5	32.4	56.9	67.9	69.5	73.2	71.8	62.7	49.0	45.1	32.9	51.8	1896
1897	25.5	32.4	41.5	49.3	56.3	68.1	75.5	69.4	66.9	58.1	42.2	32.8	51.5	1897
1898........	32.4	30.0	45.0	47.2	61.0	71.9	76.0	73.5	67.8	54.1	38.8	28.8	52.2	1898
1899........	27.8	21.6	36.9	53.3	63.3	71.5	74.1	73.7	64.1	57.4	43.9	30.2	51.5	1899
1900........	31.1	26.0	32.9	50.1	62.9	69.8	74.1	76.3	69.3	60.5	41.6	31.6	52.2	1900
1901........	29.2	21.1	39.5	46.7	59.0	70.9	78.1	73.1	64.8	53.8	37.7	27.9	50.2	1901
1902.......	27.3	22.3	41.9	48.2	62.6	66.9	74.0	68.9	63.6	54.6	48.5	29.4	50.7	1902
1903........	27.1	29.9	46.7	49.9	63.9	64.4	72.9	70.7	65.6	54.0	37.2	23.4	50.5	1903
1904........	20.7	22.9	39.7	44.4	60.7	68.4	71.4	68.8	66.5	52.2	40.5	28.0	48.6	1904
1905........	22.7	20.8	42.7	48.5	60.7	69.2	73.0	71.7	65.3	52.6	39.6	32.9	50.0	1905
1906.......	35.7	27.3	31.3	52.1	61.3	69.8	72.1	74.6	68.9	52.7	41.1	32.3	51.6	1906
1907........	32.2	26.0	45.9	42.5	54.5	65.6	72.6	69.5	65.5	48.8	39.1	33.0	49.6	1907
1908........	29.1	27.7	43.4	51.0	62.8	69.2	73.9	71.2	68.0	54.1	41.7	33.1	52.1	1908
1909........	32.2	34.7	37.3	49.1	58.7	70.1	70.7	71.9	63.2	48.8	48.9	25.4	50.9	1909
1910........	27.6	25.5	48.2	51.5	56.0	65.9	73.8	71.4	66.3	56.7	36.3	25.5	50.4	1910
1911........	32.8	34.5	37.4	47.7	66.3	70.9	74.0	72.5	67.5	53.3	37.6	36.3	52.6	1911
1912........	17.9	22.4	32.9	51.9	62.5	66.6	73.4	69.2	67.4	54.8	42.2	33.8	49.6	1912
1913........	36.0	26.7	40.1	50.0	60.3	69.8	74.5	73.3	64.1	54.1	44.4	34.5	52.3	1913
26-yr. av...	28.7	27.9	39.0	49.8	60.6	69.5	73.1	71.4	65.6	52.9	41.1	31.9	51.0	

METEOROLOGY—TABLE VI

MONTHLY RAINFALL FOR TWENTY-SIX YEARS FOR THE STATE

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Date
1888........	3.65	1.74	3.55	1.99	3.77	3.41	4.40	5.16	2.27	3.98	4.25	1.47	39.64	1888
1889........	3.13	1.35	1.38	1.79	3.71	4.13	4.19	1.50	3.62	1.78	4.02	2.81	33.41	1889
1890........	4.94	5.25	5.29	3.45	5.52	4.50	1.99	4.66	5.56	4.27	2.53	2.37	50.33	1890
1891........	2.82	4.91	4.19	2.13	2.20	4.82	3.82	3.07	1.50	1.76	5.00	2.39	38.61	1891
1892........	2.11	3.03	2.86	3.32	6.32	5.61	3.80	2.99	2.36	0.73	2.32	1.71	37.16	1892
1893........	2.56	5.13	2.09	6.37	4.97	3.34	2.49	2.17	1.57	4.24	2.09	2.61	39.63	1893
1894........	2.14	2.79	2.16	2.31	4.00	2.65	1.56	1.67	3.31	2.01	2.17	2.98	29.75	1894
1895........	4.00	0.69	1.59	2.11	1.80	2.47	2.00	2.96	1.66	1.22	4.11	3.85	28.46	1895
1896........	1.67	2.21	3.34	2.78	2.67	4.81	8.11	3.38	5.13	1.20	2.63	1.65	39.58	1896
1897........	1.93	3.64	5.17	3.27	3.93	2.85	4.65	2.72	0.78	0.64	6.62	2.39	38.59	1897
1898........	5.25	2.32	6.23	2.38	4.10	2.86	3.98	4.50	2.56	3.72	3.17	2.71	43.78	1898
1899........	3.01	2.11	4.64	1.61	4.32	2.94	4.17	1.82	2.68	2.14	1.72	3.16	34.32	1899
1900........	2.37	3.46	2.35	1.89	2.40	3.01	4.62	3.68	1.76	1.89	4.15	1.24	32.82	1900
1901........	1.70	1.24	2.66	3.40	3.96	4.44	2.72	3.33	2.86	0.73	1.53	3.79	32.36	1901
1902........	1.42	0.88	2.76	2.21	3.09	7.48	4.69	1.67	4.55	2.28	2.60	3.95	37.58	1902
1903........	2.36	4.95	3.51	4.01	2.82	4.02	3.67	3.20	1.52	2.62	2.10	2.07	36.85	1903
1904........	3.85	2.69	5.67	3.53	3.79	2.88	4.13	2.74	1.95	1.50	0.37	3.09	36.19	1904
1905........	1.73	1.58	2.50	3.10	5.63	4.72	3.93	4.46	2.86	3.65	2.63	2.29	39.08	1905
1906........	1.98	1.16	3.97	1.89	2.17	3.42	5.14	4.77	2.92	3.19	2.59	3.68	36.88	1906
1907........	6.06	0.85	5.55	2.74	3.47	4.57	5.36	2.48	3.92	2.76	1.93	3.16	42.85	1907
1908........	1.82	4.10	5.43	3.71	4.72	2.51	4.08	2.59	0.58	1.17	1.06	2.33	34.10	1908
1909........	3.24	5.39	2.77	4.13	4.72	5.86	3.76	3.56	1.78	2.31	2.52	2.62	42.66	1909
1910........	4.48	4.05	0.26	3.49	3.80	2.66	3.17	1.58	4.05	4.19	1.89	2.41	36.03	1910
1911........	3.90	1.95	2.33	4.35	1.69	3.92	2.40	5.39	4.87	4.99	2.91	3.93	42.63	1911
1912........	2.12	2.08	4.17	4.47	3.12	3.17	5.70	4.08	3.11	2.44	1.10	2.26	37.82	1912
1913........	7.01	1.94	8.40	3.35	3.53	1.87	5.20	2.52	2.37	3.36	3.52	1.68	44.75	1913
26-yr. av...	3.13	2.75	3.65	3.07	3.70	3.80	3.99	3.18	2.77	2.49	2.75	2.64	37.92	

METEOROLOGY—TABLE VII

MEAN TEMPERATURE AND RAINFALL AT THE STATION AND FOR THE STATE, 1913, AND FOR TWENTY-SIX YEARS

Temperature in degrees Fahrenheit. Rainfall in inches

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mean temperature at the Station, 1913	34.2	25.1	38.5	48.9	58.0	67.4	72.4	71.5	62.5	52.2	42.4	33.7	50.6
Twenty-six years' average temperature at the Station	27.6	26.4	37.3	48.1	58.6	67.4	71.4	69.4	64.0	51.2	40.0	30.6	49.3
Mean temperature for the State, 1913	36.0	26.7	40.1	50.0	60.3	69.8	74.5	73.3	64.1	54.1	44.4	34.5	52.3
Twenty-six years' average temperature for the State	28.7	27.9	39.0	49.8	60.6	69.5	73.1	71.4	65.6	52.9	41.1	31.9	51.0
Rainfall at the Station, 1913	7.86	2.43	11.84	3.66	3.04	0.97	4.07	4.75	3.70	3.17	3.77	1.92	51.18
Twenty-six years' average rainfall at the Station	3.45	2.82	3.74	3.01	4.03	3.86	4.25	3.56	3.35	2.54	2.79	2.68	40.08
Rainfall for the State, 1913	7.01	1.94	8.40	3.35	3.53	1.87	5.20	2.52	2.37	3.36	3.52	1.68	44.75
Twenty-six years' average rainfall for the State	3.13	2.75	3.65	3.07	3.70	3.80	3.99	3.18	2.77	2.49	2.75	2.64	37.92

METEOROLOGY—TABLE VIII

SUMMARY BY MONTHS FOR 1913

	Temperature											Number of days				Precipitation in inches			
AT THE STATION	Mean	Highest	Date	Lowest	Date	Range	Mean daily range	Greatest daily range	Date	Least daily range	Date	Clear	Partly cloudy	Cloudy	Rainfall .01 or more	Monthly rainfall	Average daily rainfall	Monthly snowfall	Prevailing wind
January	34.2	57	20	4	5	53	18.2	37	8	6	*4	4	3	24	19	7.86	.254	15.25	S. W.
February	25.1	62	19	—2	6	64	18.9	32	18	5	28	11	5	12	7	2.43	.087	11.50	S. W.
March	38.5	74	14	1	7	73	21.2	35	15	9	2	13	3	15	14	11.84	.382	6.25	S. W.
April	48.9	83	25	20	21	63	23.4	40	21	8	28	10	7	13	11	3.66	.122	T	N. W.
May	58.0	86	5	25	11	61	25.3	46	15	13	23	18	4	9	8	3.04	.098	.....	N. W.
June	67.4	96	30	32	10	64	30.3	41	6	17	8	26	2	2	6	.97	.032	.....	S. W.
July	72.4	95	*1	42	11	53	25.8	40	11	15	24	19	11	1	16	4.07	.131	.....	S. W.
August	71.5	96	17	45	25	51	27.0	35	*2	14	22	22	8	1	8	4.75	.153	.....	S. W.
September	62.5	93	*2	28	23	65	25.4	44	11	9	*18	16	5	9	9	3.70	.123	....	S. W.
October	52.2	81	*6	24	22	57	19.1	39	14	4	28	11	3	17	15	3.17	.102	.50	S. W.
November	42.4	73	22	12	12	61	18.1	40	6	5	*26	8	4	18	12	3.77	.126	18.00	S. W.
December	33.7	56	2	7	28	49	13.9	27	15	4	24	8	4	19	9	1.92	.062	6.50	S. W.
Sums and averages	50.6	96	June *30	—2	Feb. 6	98	22.2	38	May 15	4	Oct. 28	166	59	140	134	51.18	.139	58.00	S. W.
FOR THE STATE																			
January	36.0	70	*20	3	9	67	....	42	..	..	..	7	6	18	17	7.01	.230	8.6	S. W.
February	26.7	77	21	—15	6	92	....	50	..	..	..	12	6	10	8	1.94	.070	6.9	S. W.
March	40.1	80	14	—8	8	88	....	58	..	..	..	11	9	11	13	8.40	.270	5.1	S. W.
April	50.0	90	25	18	21	72	...	52	..	..	..	14	6	10	10	3.35	.112	T	N. W.
May	60.3	95	4	23	*11	72	....	54	..	..	..	14	8	9	10	3.53	.113	....	S. W.
June	69.8	105	30	29	10	76	...	48	..	..	..	20	7	3	6	1.87	.062	....	S. W.
July	74.5	103	*29	40	11	63	....	44	..	..	..	16	12	3	11	5.20	.168	....	S. W.
August	73.3	102	9	39	25	63	....	48	..	..	..	17	10	4	6	2.52	.081	....	S. W.
September	64.1	102	2	26	23	76	....	50	..	..	..	14	7	9	9	2.37	.079	T	S. W.
October	54.1	96	7	18	22	78	....	51	..	..	..	10	7	14	12	3.36	.109	0.3	S. W.
November	44.4	78	*7	2	12	76	....	51	..	..	..	10	6	14	11	3.52	.117	10.8	S. W.
December	34.5	65	2	—3	28	68	....	38	..	..	..	8	6	17	7	1.68	.065	3.7	S. W.
Sums and averages	52.3	105	June 30	—15	Feb. 6	120	....	49	..	..	..	153	91	121	119	44.75	.122	35.4	S. W.

*On other dates also.

METEOROLOGY—TABLE IX

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-SIX YEARS AT WOOSTER

	1888	1889	1890	1891	1892	1893	1894	1895	1896
AT..........	WOOSTER					EXPERIMENT STATION			
Mean temperature	47.4°	48.6°	49.5°	49.7°	48°	48.7°	50.6°	47.8°	49.3°
Highest temperature	....	91.5° *1	94.5° Aug. 3	99° Aug. 8	98° July 25	95° *5	98° July 19	98° June 4	93° Aug. 9
Lowest temperature	−5° Feb. 9	−5° *2	1° Mar. 2	0° Mar. 1	−20° Jan. 20	−9° Jan. 11	−7° Dec. 28	−6° *8	−6° Feb. 19
Range of temperature	....	96.5°	93.5°	99°	118°	104°	105°	104°	99°
Mean daily range of temperature	....	18.7°	18.9°	21°	19°	20.2°	22.9°	21.8°	19°
Greatest daily range of temperature	....	42° Apr. 23	41° Jan. 13	42° Sept. 23	46° July 17	45° Aug. 9	45° July 31	55° Oct. 6	43° May 8
Least daily range of temperature	....	2° Jan. 6	4.5° *3	4° Feb. 8	4° *4	3° *6	4° *7	1° Nov. 22	3° *9
Number of clear days	....	125	109	133	123	96	127	125	130
Number of partly cloudy days	....	103	119	117	132	164	154	117	106
Number of cloudy days	....	137	137	115	111	105	84	123	130
Number of days rain fell	....	119	149	119	119	129	130	102	134
Total yearly rainfall	38.05 inches	39.87 inches	53.94 inches	38.48 inches	41.53 inches	40.58 inches	30.78 inches	30.91 inches	39.10 inches
Greatest monthly rainfall	4.95 inches	6.73 in. July	7.45 in. Oct.	7.13 in. June	7.89 in. June	6.33 in. Feb.	4.41 in. May	4.21 in. Nov.	8.05 in. July
Least monthly rainfall	1.39 inch	1.36 in. Oct.	1.74 in Dec.	0.93 in. Sept.	0.37 in. Oct.	1.38 in. July	0.76 in. Aug.	0.41 in. Feb.	0.71 in. Oct.
Prevailing direction of wind	S.	S.	S.	S.	S. W.	S. W.	S. W.	W.	S. W.

*1 July 10 and Sept. 1. *2 Feb. 23 and 24. *3 Jan. 8 and Sept 10. *4 March 5, Nov. 1, 3 and 25, Dec. 1 and 18. *5 July 7, 25 and Sept. 7. *6 Jan. 24, Feb. 11, May 26. *7 Dec. 1 and 21. *8 Jan. 12, 13 and Feb. 5. *9 Jan. 10 and March 8.

METEOROLOGY—TABLE IX. Continued

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-SIX YEARS AT WOOSTER

	1897	1898	1899	1900	1901	1902	1903	1904	1905
AT	EXPERIMENT STATION								
Mean temperature	49.4°	50.4°	49.5°	50.7°	48.7°	49.5°	49.1°	47.1°	48.8°
Highest temperature	96° *10	96° July 3	95° Aug. 20	95° July 4	95° *12	97° May 4	94° *14	92° July 17	92° July 17
Lowest temperature	−18° Jan. 26	−9° Feb. 2	−21° Feb. 10	−10° Feb. 27	−11° Dec. 21	−9° Feb. 5	−9° Feb. 19	−21° Jan. 5	−12° Feb. 14
Range of temperature	114°	105°	116°	105°	106°	106°	103°	113°	104°
Mean daily range of temperature	21.5°	20.3°	22.9°	20.6°	20.1°	21.3°	21.6°	21.5°	20.8°
Greatest daily range of temperature	49° Oct. 5	50° Nov. 14	52° Oct. 24	43° May 6	43° April 30	45° May 4	48° Nov. 8	48° Dec. 28	42° *16
Least daily range of temperature	0° Feb. 6	5° *11	3° Feb. 18	2° Nov. 20	2° April 20	4° *13	3° *15	0° Dec. 25	2° Dec. 18
Number of clear days	124	133	126	149	152	183	148	149	144
Number of partly cloudy days	123	104	114	101	66	49	58	47	44
Number of cloudy days	118	128	125	116	147	133	159	170	177
Number of days rain fell	123	134	116	132	142	140	121	136	118
Total yearly rainfall	36.76 inches	47.85 inches	32.93 inches	36.61 inches	35.89 inches	32.95 inches	40.44 inches	41.28 inches	42.93 inches
Greatest monthly rainfall	5.76 in. Nov.	6.79 in. July	5.56 in. Nov.	5.97 in. Aug.	5.64 in. Nov.	5.55 in. June	6.58 in. Aug.	6.59 in. Apr.	7.50 in. June
Least monthly rainfall	0.29 in. Sept.	2.15 in. Sept.	0.53 in. Aug.	0.99 in. Dec.	0.79 in. Oct.	0.63 in. Jan.	1.59 in. May	0.40 in. Nov.	1.36 in. Feb.
Prevailing direction of wind	S. W.	N. W.	N. S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S

*10 July 5 and 6. *11 Jan. 21, March 2 and Dec. 18. *12 July 1, 22 and 28. *13 Jan. 22 and April 28. *14 July 4 and 9. *15 Jan. 4, Nov. 27 and Dec. 6.
*16 April 9 and May 2.

METEOROLOGY—TABLE IX. Concluded

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-SIX YEARS AT WOOSTER

AT	1906	1907	1908	1909	1910	1911	1912	1913	Summary for 26 years
	EXPERIMENT STATION								
Mean temperature	50.7°	48.4°	51.0°	50.0°	49.2°	50.8°	47.8°	50.6°	49.3°
Highest temperature	92° June 9	90° Aug. 12	95° *17	90° Sept. 14	94° *19	101° July 4	93° Sept. 10	96° *20	101° July 4, '11
Lowest temperature	−14° Feb. 7	−14° Jan. 20	−3° Feb. 9	−11° Jan. 13	−12° Feb. 19	−11° Jan. 4	−24° Jan. 13	−2° Feb. 6	−24° Jan. 13 '12
Range of temperature	106°	104°	98°	101°	106°	112°	117°	98°	125°
Mean daily range of temperature	20.6°	20.8°	23°	21.4°	23.1°	21.5°	21.4°	22.2°	21°
Greatest daily range of temperature	40° April 18	42° Jan. 20	49° Sept. 18	43° *18	51° April 14	45° Mar. 25	43° Feb. 13	46° May 15	55° Oct. 6, '95
Least daily range of temperature	2° Jan. 18	4° Aug. 6	5° Dec. 13	3° Dec. 14	3° Nov. 16	4° Mar. 28	6° Jan. 23	4° *21	0° *22
Number of clear days	130	109	141	114	127	111	140	166	132
Number of partly cloudy days	60	58	78	76	67	83	78	59	91
Number of cloudy days	175	198	147	175	171	171	148	140	142
Number of days rain fell	142	138	117	144	133	142	124	134	129
Total yearly rainfall	42.82 inches	40.00 inches	33.94 inches	44.22 inches	35.45 inches	47.15 inches	46.60 inches	51.18 inches	40.08 inches
Greatest monthly rainfall	7.38 in. Aug	6.92 in. Jau.	5.02 in. Mar.	6.44 in. Jan.	5.29 in. Jan.	6.53 in. Sept.	7.46 in. July	11.84 in. Mar.	11.84 in. Mch '13
Least monthly rainfall	1.06 in. Feb.	1.09 in. Feb.	0.73 in. Sept.	1.73 in. Sept.	0.54 in Mar.	2.25 in. Feb.	1.58 in. Feb.	.97 in. June	.29 in. Sept., '97
Prevailing direction of wind	S.	N. S. W	S. W.	S. W.	S. W.	N. W	S. W.	S. W.	S. W.

*17 Aug. 3, Sept. 24 and 25. *18 May 8 and Oct. 9. *19 July 25 and Aug. 15 and 16. *20 June 30 and Aug. 17. *21 Oct. 28 and Dec. 24 *22 Feb. 6, 1897, and Dec. 25, 1904.

METEOROLOGY—TABLE X

SUMMARY BY YEARS AND GRAND SUMMARY FOR THIRTY-ONE YEARS FOR THE STATE

FOR THE STATE	1883	1884	1885	1886	1887	1888	1889	1890
Mean temperature	49.4°	50.6°	48.0°	49.6°	52.0°	49.5°	51.1°	52.2°
Highest temperature	98° Aug. 22	102° Sept. 28	101° July 21	98.6° July 18	108° July 18	102° Aug. 3	99.5° Aug. 31	103.1° Aug. 3
Lowest temperature	—18° Jan. 22	—34° Jan. 25	—31° Jan. 29	—21.5° Jan. 12	—21° Jan. 7	—15° Jan. 27	—13.5° Feb. 24	—4° Mar. 7
Range of temperature	115.5°	133°	132°	120.1°	29°	117°	113°	107.1°
Greatest daily range of temperature	55.2° Mar. 18	50° *2	58.5° Jan. 30	57° Dec. 11	57° Dec. 11	50°	53° Mar. 30	48.5 Apr. 11
Average number of days rain fell	146	145	148	131	121	125	118	149
Mean yearly rainfall	44.98 inches	36.19 inches	38.06 inches	36.71 inches	33.63 inches	39.64 inches	33.41 inches	50.33 inches
Mean daily rainfall	.123 inch	.099 inch	.104 inch	.101 inch	.092 inch	.108 inch	.092 inch	.138 inch
Prevailing direction of wind	S. W.......	S. W.......	S. W	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......

	1891	1892	1893	1894	1895	1896	1897	1898
Mean temperature	51.8°	50.2°	50.0°	52.4°	50.0°	51.8	51.5°	52.2
Highest temperature	101° Aug. 10	103° July 25	102° June 19	105° *4	106° July 20	103° Apr. 17	113° July 4	105° July 1
Lowest temperature	—5° Mar. 5	—27° Jan. 20	—24° Jan. 11	—27° Dec. 29	—24° Feb. 6	—18° *6	—27° Jan. 26	—20° Feb. 3
Range of temperature	109°	128°	126°	132°	130°	121°	140°	125°
Greatest daily range of temperature	50° *3	51° Sept. 25	54.6°	60° Oct. 19	59° *5	53° Mar. 25	67° *7	....
Average number of days rain fell	120	121	113	100	89	124	110	121
Mean yearly rainfall	38.61 inches	37.16 inches	39.63 inches	29.75 inches	28.46 inches	39.58 inches	38.59 inches	43.78 inches
Mean daily rainfall	.106 inch	.102 inch	.109 inch	.081 inch	078 inch	.108 inch	.106 inch	.119 inch
Prevailing direction of wind	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......

*1 Sept. 28. *2 Sept. 5 and Dec. 4. *3 April 27 and 30. *4 July 18 and 19. *5 Jan. 15 and March 29. *6 Feb. 20 and 21. *7 Sept. 25 and 26.

METEOROLOGY—TABLE X. Concluded

SUMMARY BY YEARS AND GRAND SUMMARY FOR THIRTY-ONE YEARS FOR THE STATE

FOR THE STATE	1899	1900	1901	1902	1903	1904	1905	1906
Mean temperature	51.5°	52.2°	50.2°	50.7°	50.5°	48.6°	50.0°	51.6
Highest temperature	107° Sept 6	103° *8	109° July 22	100° July 8	104° July 25	99° *10	100° July 10	101° Aug. 21
Lowest temperature	—37° Feb. 10	—20° *9	—20° Feb. 23	—17° Feb. 14	—20° Feb. 19	—30° Jan. 4	—22° Feb. 3	—23° Feb. 6
Range of temperature	144°	123°	129°	117°	124°	129°	120°	124°
Greatest daily range of temperature	....	57° Feb. 9	61° Dec. 14	56° May 4	60° Sept. 25	54° Jan. 5	57° May 24	54° Oct. 13
Average number of days rain fell	107	107	107	114	111	117	118	124
Mean yearly rainfall	34.32 inches	32.82 inches	32.36 inches	37.58 inches	36.85 inches	36.19 inches	39.08 inches	36.88 inches
Mean daily rainfall	.094 inch	.090 inch	.089 inch	.103 inch	.101 inch	.099 inch	.107 inch	.101 inch
Prevailing direction of wind	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......

	1907	1908	1909	1910	1911	1912	1913	Summary for 31 years
Mean temperature	49.6°	52.1°	50.9°	50.4°	52.6°	49.6°	52.3°	50.8°
Highest temperature	98° July 22	104° Aug. 3	97° July 30	100° Aug. 17	107° July 4	101° July 15	105° June 30	113° July 4 '97
Lowest temperature	—23 Jan. 6	—22° Feb. 9	—20° Dec. 30	—25° Feb. 19	—19° Jan. 4	—37° Jan. 13	—15° Feb. 6	—39° Feb. 10, '99
Range of temperature	117°	126°	117°	125°	126°	138°	120°	152°
Greatest daily range of temperature	57° Feb. 13	60° Oct. 5	51°	....	....	....	....	....
Average number of days rain fell	129	111	124	112	127	112	120	120
Mean yearly rainfall	42.86 inches	34.10 inches	42.65 inches	36.03 inches	42.63 inches	37.82 inches	44.75 inches	37.92 inches
Mean daily rainfall	.117 inch	.093 inch	.117 inch	.099 inch	.117 inch	.104 inch	.123 inch	.104 inch
Prevailing direction of wind	S. W.......	S. W.	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.........

*8 July 4, Aug. 6 and 10. *9 Jan. 20 and Feb. 27. *10 July 17 and Sept. 29.

METEOROLOGY TABLE XI

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-SIX YEARS AT WOOSTER

Date	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	..	—5	..	—1	..	8	..	19	..	31	..	42	..	43	..	41	..	31	..	27	..	21	..	9
1889	54	12	54	—5	71	16	80	21	90	30	87	38	92	49	90	45	92	37	76	23	65	16	65	18
1890	66	5	65	14	60	1	74	23	83	30	88	46	94	45	95	40	88	38	81	30	66	24	48	15
1891	51	12	60	3	61	0	83	21	82	28	89	44	89	49	99	53	98	42	88	25	71	10	58	16
1892	54	—20	54	6	65	10	76	28	86	38	90	56	98	48	92	49	88	36	81	25	67	16	61	—2
1893	51	—9	47	—2	75	10	83	24	84	36	92	45	95	47	93	37	95	28	85	24	66	15	62	6
1894	56	1	64	—1	75	14	92	24	83	35	93	37	98	41	96	41	93	36	80	28	65	31	57	—7
1895	54	—6	60	—6	59	9	80	21	94	27	98	35	92	42	94	42	93	34	73	19	72	18	61	—2
1896	53	—2	58	—6	65	4	89	19	86	44	87	39	92	45	93	41	92	34	71	21	69	13	56	1
1897	61	—18	54	0	69	11	79	21	78	31	88	37	96	50	92	42	96	28	86	25	65	12	60	2
1898	64	—1	64	—9	71	12	77	16	81	32	90	40	96	45	90	46	90	38	86	24	66	13	56	1
1899	55	—6	57	—21	67	9	86	21	86	30	92	40	94	45	95	39	94	32	92	22	66	22	63	—2
1900	54	—5	65	—10	57	—4	78	20	89	25	90	44	95	44	94	49	89	41	86	30	69	6	55	11
1901	53	—4	40	0	69	—1	82	22	82	33	91	38	95	50	94	47	86	34	79	26	67	18	64	—11
1902	47	2	59	—9	69	9	83	24	97	29	89	39	93	46	88	40	85	32	77	27	72	24	60	—5
1903	60	—8	63	—9	76	21	74	19	89	27	88	41	94	42	92	43	89	32	79	26	71	9	49	—2
1904	60	—21	57	—10	74	13	72	12	88	33	88	44	92	46	90	42	89	31	83	19	68	15	63	—1
1905	59	—8	43	—12	79	10	77	23	82	31	89	38	92	50	90	46	87	36	80	23	61	16	52	13
1906	72	6	65	—14	61	—5	80	21	86	29	92	47	88	46	91	48	90	44	74	22	72	23	58	6
1907	67	—14	50	—5	82	12	78	15	81	29	89	40	88	40	90	43	88	34	82	22	55	18	56	9
1908	51	4	56	—3	75	21	80	24	89	30	91	36	92	46	95	43	95	28	84	24	68	17	59	7
1909	66	—11	60	—2	60	12	81	13	84	31	89	42	89	45	89	41	90	30	81	22	72	21	68	—6
1910	45	—1	48	—12	84	18	81	23	82	25	90	35	94	44	94	38	91	34	85	24	66	14	49	0
1911	56	—11	62	9	67	4	77	16	92	28	94	46	101	43	97	41	87	37	75	22	65	10	61	7
1912	44	—24	55	—16	68	6	78	23	86	36	88	31	90	51	89	41	93	30	82	26	68	18	58	8
1913	57	4	62	—2	74	1	83	20	86	25	96	32	95	42	96	45	93	28	81	24	73	12	56	7
Extremes	72	—24	65	—21	84	—5	92	12	97	25	98	31	101	40	99	37	98	28	92	19	73	6	68	—11

METEOROLOGY—TABLE XI. Concluded

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-SIX YEARS FOR THE STATE

Date	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	68	-15	68	-10	77	-6	92	19	91	23	102	34	97	42	102	35	92	26	80	22	80	17	62	1
1889	61	-8	70	-14	82	10	88	15	96	26	92	38	98	46	100	40	98	28	82	17	77	9	73	10
1890	75	1	73	5	69	-4	86	20	92	28	101	39	101	43	103	40	92	33	85	29	76	17	65	3
1891	65	3	80	-2	74	-5	95	15	93	25	98	40	95	41	101	39	99	36	93	20	76	0	66	9
1892	61	-27	74	-1	80	-6	90	14	99	28	101	47	103	40	99	45	96	34	89	20	76	8	70	-12
1893	63	-24	68	-14	87	-8	93	20	94	23	102	40	101	42	101	37	100	24	95	15	76	-2	72	-5
1894	66	-16	76	-15	91	3	97	16	98	31	102	29	105	36	104	36	103	27	90	15	79	4	70	-27
1895	62	-19	70	-24	86	-7	90	16	102	19	105	29	106	34	103	31	105	25	84	8	85	5	79	-13
1896	70	-14	78	-18	73	-7	103	15	99	36	98	33	102	39	102	35	100	25	85	17	79	7	67	-15
1897	71	-27	72	-9	82	5	92	11	91	25	102	31	113	44	101	38	105	25	97	20	76	8	71	-7
1898	71	-18	72	-20	84	5	87	10	92	29	99	39	105	38	100	40	102	33	96	20	76	2	67	-18
1899	66	-15	67	-39	76	0	94	6	96	28	102	36	105	41	104	39	107	26	94	20	79	18	69	-7
1900	67	-20	80	-20	70	-9	87	15	97	20	96	38	103	38	103	40	100	33	93	23	80	0	65	-2
1901	67	-10	60	-20	84	-8	91	18	90	26	103	30	109	48	101	42	98	29	88	20	79	10	73	-19
1902	63	-11	66	-17	82	-4	90	17	98	24	98	33	100	43	97	37	94	24	88	21	87	17	63	-11
1903	73	-13	69	-20	85	11	88	10	93	22	95	35	104	42	101	38	98	26	93	15	88	2	57	-11
1904	70	-30	75	-18	86	-1	81	7	95	27	98	37	99	41	97	38	99	23	92	15	75	0	69	-16
1905	65	-17	54	-22	85	-5	89	12	93	26	99	34	100	44	96	41	95	30	89	20	71	10	58	2
1906	79	-14	72	-23	74	-12	91	18	94	24	100	34	98	43	101	43	98	36	91	18	82	14	68	-15
1907	75	-23	66	-19	96	-2	86	10	89	24	96	36	98	37	96	40	93	29	88	19	71	11	69	2
1908	59	-8	66	-22	85	12	91	16	96	25	100	33	102	42	104	37	100	24	90	15	77	5	68	-2
1909	74	-17	70	-17	70	6	90	13	91	24	96	36	97	40	96	35	95	25	86	16	80	15	75	-20
1910	62	-24	68	-25	90	12	88	19	88	21	97	33	98	43	100	36	93	34	94	18	78	11	63	-10
1911	68	-19	76	-2	81	1	86	8	101	25	101	40	107	41	104	34	97	33	88	20	79	8	79	-3
1912	57	-37	68	-25	80	-3	89	15	91	31	93	28	101	42	95	40	99	29	93	23	82	8	74	-5
1913	70	3	77	-15	80	-8	90	18	95	23	105	29	103	40	102	39	102	26	96	18	78	2	65	-3
Extremes	79	-37	80	-39	96	-12	103	6	102	19	105	28	113	34	104	31	107	23	97	8	88	-2	79	-27

TABLE XII: MONTHLY RAINFALL AT DISTRICT TEST-FARMS

Rainfall—inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
Strongsville														
1897	.91	1.62	3.29	3.88	5.99	1.88	5.56	3.25	1.13	.87	7.02	1.92	37.32	1897
1898	5.47	3.75	4.82	2.37	3.43	5.60	4.25	5.69	2.72	5.59	3.25	7.39	54.33	1898
1899	4.35	2.32	5.25	3.11	5.58	2.10	5.75	.61	3.14	2.86	1.55	6.36	42.98	1899
1900	3.22	5.53	3.01	2.22	1.85	1.36	4.73	2.49	3.56	2.22	4.91	1.94	37.04	1900
1901	2.73	2.20	4.35	4.76	5.14	3.32	3.15	7.46	5.51	.47	2.51	5.34	48.94	1901
1902	1.17	1.40	2.64	2.91	4.29	9.34	7.39	4.52	5.58	2.73	2.35	3.34	47.68	1902
1903	2.37	2.97	3.18	6.68	1.45	3.78	6.49	8.72	1.88	3.09	2.70	2.62	45.93	1903
1904	6.51	3.59	4.68	3.47	6.07	1.45	5.80	3.48	2.73	1.20	.50	3.87	43.35	1904
1905	2.48	2.73	3.24	3.97	4.38	2.18	5.04	4.11	3.50	2.95	2.92	1.66	39.16	1905
1906	2.03	2.06	....	1.93	1.01	4.67	2.72	4.30	6.70	....	4.77	5.12	.....	1906
1907	5.21	1.20	....	....	....	....	....	....	....	....	....	....	.....	1907
1908	....	....	....	....	2.82	2.78	3.70	3.10	1.00	1.60	1.08	1.90	.....	1908
1909	2.48	2.56	....	3.49	4.13	3.20	4.40	3.60	2.71	2.60	2.80	1.30	.....	1909
1910	4.80	2.21	1.10	....	3.05	2.50	1.00	1.37	4.85	3.90	3.98	2.99	.....	1910
1911	....	1.16	1.85	3.03	1.95	1.80	.80	3.28	5.33	3.85	....	1.51	.....	1911
1912	1.38	1.49	2.91	5.12	3.62	1.80	6.88	4.74	4.34	2.40	.20	1.89	36.77	1912
1913	4.50	1.45	9.30	2.08	2.15	1.30	2.60	1.70	3.30	3.59	2.61	1.13	35.71	1913
Av.......	3.31	2.39	3.82	3.50	3.56	3.07	4.39	3.90	3.62	2.66	2.88	3.14	42.65	

TABLE XII: MONTHLY RAINFALL AT DISTRICT TEST-FARMS—Continued

Rainfall—inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
Germantown														
1905	....	....	....	3.45	7.70	3.00	3.80	7.90	3.56	4.10	2.24	2.28	.....	1905
1906	2.92	1.07	6.93	1.88	1.34	2.88	6.24	7.46	2.30	1.65	3.80	4.32	42.79	1906
1907	7.22	.32	6.25	2.26	3.20	3.65	4.10	1.93	5.64	2.92	3.25	3.22	43.96	1907
1908	2.11	6.33	4.24	4.53	4.47	1.42	3.86	1.36	.35	.27	1.70	1.31	31.95	1908
1909	3.41	7.67	2.07	5.58	6.98	5.93	4.50	3.34	.89	3.13	1.95	4.00	49.45	1909
1910	3.00	4.25	.10	1.87	5.08	1.58	3.95	1.11	3.96	7.60	.96	2.85	36.41	1910
1911	5.00	1.46	3.00	6.01	1.36	2.67	1.78	4.56	5.16	4.48	3.06	3.81	42.35	1911
1912	3.23	1.68	4.29	6.51	3.49	2.24	3.78	9.05	2.50	2.79	.72	3.30	43.58	1912
1913	8.40	2.05	7.32	5.25	2.62	2.40	3.49	2.23	2.33	2.56	4.80	.88	44.33	1913
Av.....	4.41	3.10	4.28	4.15	4.03	2.86	3.94	4.33	2.97	3.28	2.50	2.89	41.85	
Carpenter														
1903	....	....	....	3.75	5.69	5.07	4.23	1.02	1.02	2.60	2.73	3.28	.....	1903
1904	3.74	2.89	5.07	3.03	2.69	3.16	3.79	2.71	2.08	1.10	.18	3.40	33.84	1904
1905	1.02	1.35	4.07	2.70	7.02	5.11	3.77	4.11	1.02	5.20	2.45	3.51	41.33	1905
1906	3.58	1.85	3.82	1.43	1.40	6.39	1.40	2.92	3.24	2.58	3.50	3.50	35.61	1906
1907	8.94	2.28	6.13	3.57	3.47	4.49	4.84	4.10	2.94	2.38	2.14	1.72	47.00	1907
1908	1.37	4.31	7.80	5.15	4.36	2.92	3.74	3.50	.46	.85	1.37	2.13	37.98	1908
1909	3.05	5.72	2.77	4.10	4.29	7.63	4.18	2.18	.86	2.12	.90	2.05	39.85	1909
1910	6.40	4.70	.20	3.23	2.91	2.35	3.40	1.74	.99	1.66	1.42	2.80	31.82	1910
1911	5.56	3.08	2.26	3.90	2.06	6.14	1.19	4.69	5.18	3.68	2.20	4.01	43.95	1911
1912	1.48	2.44	3.39	4.04	2.90	2.92	5.46	2.56	2.51	1.80	.38	2.09	31.97	1912
1913	6.78	1.98	1.71	2.74	4.23	2.29	2.64	2.38	2.07	2.89	2.34	2.36	34.41	1913
Av.....	4.19	3.06	3.72	3.42	3.73	4.41	3.51	2.90	2.04	2.44	1.78	2.80	37.78	

THIRTY-THIRD ANNUAL REPORT

FOR 1913-1914

PRESS BULLETINS—INDEX

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JUNE, 1914

BULLETIN 278

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

Thirty-Third Annual Report

OF THE

Ohio Agricultural Experiment Station

For the Year ending June 30, 1914

Published by order of the State Legislature

WOOSTER, OHIO
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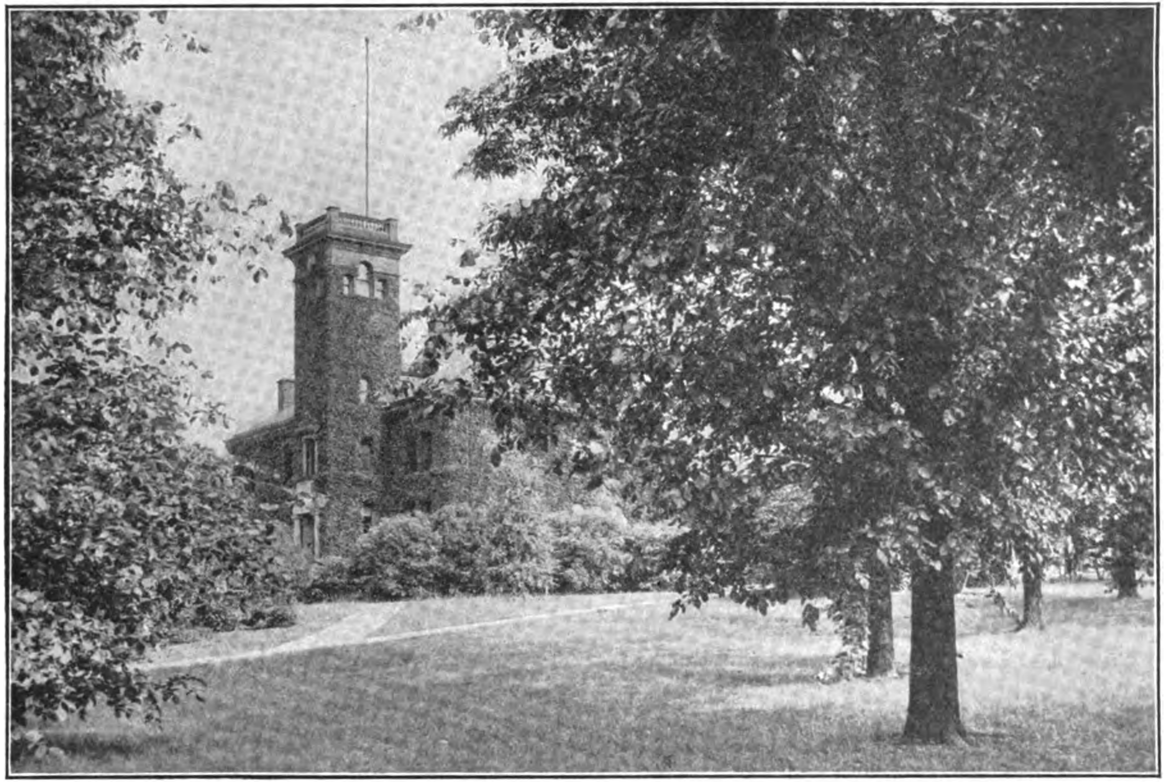
1914



Administration Building, Ohio Agricultural Experiment Station

ANNOUNCEMENT

The Ohio Agricultural Experiment Station is organized under an act of the General Assembly of Ohio, passed April 17, 1882, and supplemented by an act of Congress, approved March 2, 1887.

WHAT THE STATION CAN DO

The Station offers its advice and assistance to the farmers of Ohio along the following lines:

The maintenance of soil fertility, including the rotation of crops and the selection and use of manures and fertilizing materials.

The selection of varieties of grains, grasses and forage crops and methods of culture.

The selection of varieties of fruits and vegetables and the management of orchards.

The examination of seeds that are suspected of being unsound or adulterated; the identification of grasses, weeds and other plants; the prevention of fungous diseases of plants.

The identification of insects and the control of such as are injurious.

The feeding of animals, including calculation of rations and use of various feeding stuffs.

The planting and care of forest trees and the management of farm woodlots.

WHAT THE STATION CANNOT DO

For advice and assistance along the following lines, application should be made to the Ohio Agricultural Commission, Columbus, not to the Experiment Station.

The analysis of commercial fertilizers, of lime or limestone for agricultural purposes, and of feeding stuffs.

The treatment of contagious diseases of animals.

The inspection of orchards and nurseries for the control of San Jose scale.

The examination of foods, drugs, and dairy products suspected of being adulterated.

The Station is not prepared to analyze drinking water; requests for such analysis should be addressed to the Secretary of the State Board of Health, Columbus.

Visitors to the Station or its various test farms are welcome at all times during business hours. Persons or parties who contemplate such visits and who desire special attention are requested to write in advance, giving date of proposed visit and probable number of party.

Any citizen of Ohio has the right to apply to the Station for such assistance as it can give, and all such requests will receive prompt attention.

The Bulletins of this Station are sent free to all residents of the State who request them.

Address all communications to
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THE MAINTENANCE OF FERTILITY

LIMING THE LAND

By C. E. THORNE

In Bulletin 159 of this Station is reported the plan and earlier results of an experiment in the use of lime on crops grown in a 5-year rotation of corn, oats, wheat, clover and timothy.

There are five tracts of land in this experiment, named A, B, C, D, and E, so that each crop may be grown every season. Each tract is subdivided into 30 plots, containing one-tenth acre each, the plots being separated by paths 2 feet wide. The diagram shows the arrangement of plots and scheme of fertilizing, the fertilizers being applied to the cereal crops only; the clover and timothy, which are sown together, following without any further treatment. Every third plot, beginning with No. 1, is left continuously without fertilizer or manure. A tile drain is laid 30 inches deep under alternate paths, thus spacing the drains 36 feet apart.

The experiment is located on land which had been subjected to an exhaustive system of husbandry, the soil being a light, silty clay, overlying the shaly sandstones of the Upper Waverly.

From the beginning of the test, in 1894, there was difficulty in securing a satisfactory stand of clover, and this difficulty increased from year to year. In 1900 a dressing of one ton per acre of caustic lime was applied to the west half of Section E, as it was being prepared for corn, the lime being applied after plowing and harrowed in. The lime was applied to all the land, fertilized and unfertilized alike. This treatment was repeated on the west half of each of the succeeding sections as they came under corn until Section E was reached again, in 1905, when the liming was transferred to the east half, and continued on that half for three years. By this time it was demonstrated that the differences which were being shown

in the crops were due to the liming and not to natural variations in soil, and the liming was returned to the west half, and has since been continued on that half only. Because of this shifting of the liming, sections E, B and A have had one liming on the east end, which has reduced the contrast between the two ends, so that the results which follow do not show the full effect of the treatment.

After going once over the 5 sections with quicklime, ground limestone was substituted and has been used at the rate of one ton per acre, thus carrying only about half as much calcium and magnesium as was used at first. This reduction in quantity was made because it was apparent that the full effect of the first liming had not been exhausted by the five crops of the rotation; but the later crops are indicating a need for more lime and the quantity of limestone was increased to 2 tons for the corn crop of 1914.

In 1903 the corn was so injured by white grub that no trustworthy contrast could be made between the two halves of the section (C) and in 1912 the crop was again so injured by the same pest (on Section A) that the crop was plowed under.

EFFECT OF LIME ON CORN

In Table I is given the average yield of the 12 crops of corn harvested during the period 1900-1913, the data being arranged in groups according to the principal treatments, and omitting the plots which have received only partial fertilizing, and No. 30, the plan of which was changed after several years of low fertilizing.

Table I shows that the liming has added materially to the yield of corn under every treatment and on the untreated land. The lowest gain for lime is found on the plot receiving phosphorus in basic slag, and the highest gains are on the plots receiving nitrogen in oilmeal, dried blood and sulphate of ammonia. Without lime, these carriers of nitrogen produce less total corn than does nitrate of soda, but with lime they surpass the nitrate in yield. Wherever nitrate of soda is used in the fertilizer it increases the total yield but reduces the demand for lime; the larger the applications of nitrate the greater this reduction, but no practicable application of nitrate is able to obviate the necessity for liming.

The last two columns of the table show the increase produced by the fertilizers in addition to that caused by the liming. In calculating this increase it is assumed that the variations in the yield of neighboring plots are likely to be progressive. That is, that if Plots 1 and 4, unfertilized, yield 30 and 33 bushels respectively, the probable unaided yields of Plots 2 and 3 would have been 31 and 32 bushels.

TABLE I: Average yield of CORN and increase from lime and from fertilizers for 12 years, 1900-1913, (excluding 1903 and 1912) Bushels per acre

Treatment (Fertilizers per acre for complete rotation)	Plot No.	Yield per acre		Gain for lime	Increase from fertilizers	
		Unlimed	Limed		Unlimed	Limed
I: Without nitrogen:						
Phosphorus, 20 lbs. in acid phosphate	2	36.13	43.64	7.51	9.85	9.08
Phosphorus, 20 lbs.; potassium, 108 lbs. in muriate of potash	8	43.86	51.68	7.82	17.14	17.82
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	48.85	56.29	7.42	24.22	23.60
" " linseed oilmeal	21	45.89	57.56	11.67	22.13	23.06
" " dried blood	23	47.16	57.19	10.03	22.76	22.73
" " sulphate of ammonia	24	45.80	57.68	11.88	20.08	22.52
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs.; and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	49.06	55.73	6.67	22.94	22.64
" " bonemeal	26	45.53	52.99	7.46	17.85	17.01
" " dissolved boneblack	27	48.60	54.77	6.17	20.29	18.68
" " basic slag	29	48.71	52.07	3.36	19.76	15.88
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	50.12	55.45	5.33	24.39	22.24
V: Yard manure, estimated to carry nitrogen 144 lbs.; phosphorus 48 lbs.; and potassium, 112 lbs.	18	56.02	62.71	6.69	31.14	28.37
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs.	20	56.02	51.93	8.83	18.65	16.68
Average unfertilized yield		25.96	34.21	8.25	.....	.....

The average yield of all the unfertilized plots is given as a comparison between the yields of different seasons, but it is never used in the calculation of increase. The increases shown in the table and those following, therefore, are those calculated from the yields of neighboring unfertilized or check plots. In the case of the unlimed land these plots have had neither lime nor fertilizer, while on the limed land the check plots have had lime but no fertilizer. In the case of the low-nitrogen treatment the fertilizers have usually produced as much increase of corn on the limed as on the unlimed land, but on the high-nitrogen plots, including the manured plots, the increase from the fertilizers is greater on the unlimed land, thus indicating that a part of the effect of liming has been the favoring of nitrification.

EFFECT OF LIME ON OATS

Table II shows the average yields of 10 crops of oats harvested in this experiment, the crops of 1902, 1903 and 1904 not having been separately harvested. The table indicates a much smaller effect on the oats crop than that found in the corn crop. It is possible that a part of this difference may be due to the fact that the corn stubble is always plowed for oats in this test, thus turning down the lime that had been applied on the surface for the corn. With the oats, as with the corn, the greatest increase from the liming is found in the low-nitrogen plots, the one to which the nitrogen is carried in sulphate of ammonia leading. On several of the high-nitrogen plots there is an actual loss of crop after liming. It will be observed that the manured plots do not receive manure on the oats crop, that crop following as a gleaner after corn.

EFFECT OF LIME ON WHEAT

Table III shows that the wheat crop is responding regularly to the liming, the only treatment which fails to show a larger yield on the limed than on the unlimed land being the one in which the phosphorus is carried in basic slag. The largest increase from lime is found on the plot receiving its nitrogen in sulphate of ammonia. Without lime this plot falls 2½ bushels below the one dressed with nitrate of soda, but with lime the two carriers of nitrogen give exactly the same yield. On the no-nitrogen and low-nitrogen plots, excepting No. 21, the increase from fertilizers is greater on the limed than on the unlimed land.

EFFECT OF LIME ON CLOVER

The oat-stubble is plowed for wheat, thus bringing the lime near the surface again, besides mixing it very thoroughly through the soil, and the clover responds to the liming with a larger rate of

TABLE II: Average yield of OATS and increase from lime and from fertilizers for the 10 years, 1901, and 1905 to 1913, inclusive.
Bushels per acre

Treatment (Fertilizers per acre for complete rotation)	Plot No.	Yield per acre		Gain or loss (—) for lime	Increase from fertilizers	
		Unlimed	Limed		Unlimed	Limed
I: Without nitrogen:						
Phosphorus, 20 lbs. in acid phosphate	2	39.20	42.07	2.87	10.74	11.00
Phosphorus, 20 lbs., potassium, 108 lbs. in muriate of potash	8	42.57	46.07	3.50	15.73	16.27
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	51.18	50.55	—.63	23.55	21.19
" " linseed oilmeal	21	47.09	49.86	2.77	20.16	19.79
" " dried blood	23	47.61	48.47	.	20.86	18.41
" " sulphate of ammonia	24	46.23	50.04	3.81	19.19	19.50
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs., and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	49.61	47.61	−2.00	22.35	18.06
" " bonemeal	26	45.06	45.20	.14	16.99	14.23
" " dissolved boneblack	27	47.59	46.40	−1.19	18.77	15.50
" " basic slag	29	45.66	44.54	−1.12	16.10	13.70
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs, and potassium, 108 lbs.	12	47.87	48.80	.93	20.60	19.00
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus 48 lbs., and potassium, 112 lbs.	18	42.08	43.48	1.40	14.32	13.27
Yard manure, estimated to carry nitrogen 72 lbs. phosphorus, 24 lbs., and potassium, 56 lbs.	20	36.04	39.72	3.68	8.63	9.15
Average unfertilized yield		27.51	30.23	2.72	....	.....

increase than is given by any other crop. Not only does the clover show a great direct increase from the liming, but in every instance, excepting only the plot to which phosphorus is carried in basic slag, the residual increase from the fertilizers which have been applied to the previous crops is materially greater on the limed than on the unlimed land.

The effect of nitrate of soda is strikingly brought out in the comparison of Plots 17, 21, 23 and 24, and of this group of plots with those receiving the larger quantity of nitrate. On the unlimed land the increase from the complete fertilizers used on Plots 21, 23 and 24 is no greater in the average than on Plot 8, which receives no nitrogen, while that on Plot 17 is materially greater. The behavior of the clover crop is very different from that of the cereal crops, for although in these crops also nitrate of soda has been more effective than the other carriers of nitrogen, the difference has been less conspicuous than with the clover, notwithstanding the fact that nitrate of soda is supposed to be relatively more evanescent in its effect, as compared with nitrogen in organic materials. Considering all the evidence the conclusion seems to be warranted that a part of the superior effect of nitrate of soda on this acid soil has been due tc the sodium contained, that element having been liberated when the salt was being decomposed to give up its nitrogen to the crops which preceded the clover.

That the increase in the quantity of nitrate of soda, as used on Plot 12, has not produced a greater effect, may be explained on the assumption that the formula used on this plot has not carried enough phosphorus or potassium, one or both, to properly balance the nitrogen given, and hence a considerable part of the nitrate has been wasted.

On the third group of plots the proportion of clover in the stand has been conspicuously greater on the unlimed land to which the phosphorus is carried in bonemeal or basic slag than under other treatments, and this has been especially the case on the manured land. The manured plots have also grown more timothy and fewer weeds during the season immediately after seeding than the fertilized land. The gain for lime, moreover, has been relatively smaller on the manured than on fertilized land. These points are explained by the absence of sulphuric acid in the manure and the bonemeal and basic slag mixture, and by the considerable amount of lime carried in the manure.

But neither nitrate of soda nor bonemeal nor basic slag nor any practicable combination of these materials, will furnish sufficient alkali to neutralize this acid soil, unless used in such quantity that the cost will be prohibitive.

TABLE III: Average yield of WHEAT and increase frcm lime and from fertilizers for the 8 years, 1906-1913. Bushels per acre.

Treatment (Fertilizers per acre for complete rotation)	Plot No.	Yield per acre		Gain or loss (—) for lime	Increase from fertilizers	
		Unlimed	Limed		Unlimed	Limed
I: Without nitrogen:						
Phosphorus, 20 lbs. in acid phosphate	2	20.90	24.19	3.29	7.47	8.54
Phosphorus 20 lbs., potassium, 108 lbs. in muriate of potash	8	21.67	24.29	2.62	8.08	9.05
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	25.89	28.80	2.91	13.88	14.61
" " linseed oilmeal	21	24.81	26.75	1.94	12.88	11.73
" " dried blood	23	23.07	26.92	3.85	11.26	12.06
" " sulphate of ammonia	24	23.38	28.80	5.42	11.35	13.90
III: Nitrogen, 76 lbs., in nitrate of soda, with phosphorus, 20 lbs., and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	30.70	30.82	.12	17.44	15.71
" " bonemeal	26	26.18	27.23	1.05	14.06	12.40
" " dissolved boneblack	27	26.61	28.68	2.07	14.64	13.96
" " basic slag	29	27.87	26.46	—1.41	16.04	11.85
IV: Nitrogen, 114 lbs, in nitrate of sod with phosphorus, 20 lbs. and potassium, 108 lbs.	12	29.60	32.89	3.29	16.73	17.65
V: Yard manure, estimated to carry nitrogen 114 lbs., phosphorus 48 lbs., and potassium, 112 lbs.	18	28.40	31.42	3.02	16.09	16.60
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs.	20	23.23	26.02	2.79	10.96	10.79
Average unfertilized yield		12.64	15.01	2.37	....	....

TABLE IV: Average yield of CLOVER HAY and increase from lime and from ferti'izers for 11 years, 1903-1913
Pounds per acre

Treatment (Fertilizers per acre for complete rotation, all applied for corn, oats and wheat)	Plot No.	Yield per acre: Unlimed	Yield per acre: Limed	Gain for lime	Increase from fertilizers: Unlimed	Increase from fertilizers: Limed
I: Without nitrogen:						
Phosphorus, 20 lbs. in acid phosphate	2	1,554	2,250	696	461	700
Phosphorus, 20 lbs., potassium, 108 lbs. in muriate of potash	8	2,286	3,476	1,190	883	1,439
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	2,596	3,842	1,246	1,287	1,968
" " linseed oilmeal	21	2 256	3,409	1,153	963	1,589
" " dried blood	23	2,123	3,515	1,392	793	1,708
" " sulphate of ammonia	24	2,256	3,736	1,480	859	1,842
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus 20 lbs., and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	2,796	3,631	835	1,438	1,718
" " bonemeal	26	3,135	3,981	846	1,654	1,978
" " dissolved boneblack	27	2,636	3,524	888	1,137	1,497
" " basic slag	29	3,072	3,579	507	1,554	1,530
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	2,853	3,765	912	1,481	1,845
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus 48 lbs. and potassium, 112 lbs.	18	3,582	4,708	1,126	2 253	2,761
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs. and potassium, 56 lbs.	20	2,517	3,312	795	1,195	1,392
Average unfertilized yield		1,409	1,983	574	.....	.....

TABLE V: Average yield of TIMOTHY HAY and increase from lime and from fertilizers for 7 years, 1906 to 1913 (excluding 1909)
Pounds per acre

Treatment (Fertilizers per acre for complete rotation, all applied on corn, oats and wheat)	Plot No.	Yield per acre		Gain for lime	Increase from fertilizers	
		Unlimed	Limed		Unlimed	Limed
I: Without nitrogen:						
Phosphorus 20 lbs. in acid phosphate	2	2,992	3,934	942	292	803
Phosphorus, 20 lbs., potassium, 108 lbs. in muriate of potash	8	2,982	4,008	1,026	546	819
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	3,197	4,635	1,438	839	1,456
" " linseed oilmeal	21	3,068	4,416	1,348	717	1,234
" " dried blood	23	2,987	4,388	1,401	548	1,185
" " sulphate of ammonia	24	2,923	4,617	1,694	365	1,261
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs, and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	3,507	4,389	882	1,081	1,273
" " bonemeal	26	3,436	4,876	1,442	744	1,352
" " dissolved boneblack	27	3,184	4,607	1,423	480	1,068
" " basic slag	29	3,837	4,567	730	1,120	1,014
IV: Nitrogen, 114 lbs., in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	3,517	4,434	917	1,078	1,391
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus, 48 lbs, and potassium, 112 lbs.	18	4,470	5,742	1,272	2,083	2,430
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs	20	3,627	4,841	1,214	1,244	1,527
Average unfertilized yield		2,512	3,225	713	.....	.....

EFFECT OF LIME ON TIMOTHY

The results on the timothy crop are given in Table V. On the unlimed land the timothy crop shows the same neglect of organic and ammonia nitrogen on Plots 21, 23 and 24, as compared with Plot 8, as that shown by the clover, but shows a somewhat greater response than clover to these carriers of nitrogen after lime has been added. The increase of nitrogen in nitrate of soda, in Group III, accompanied as it has been by a reduction of phosphorus, has not produced a further increase in yield on the limed land.

The total gain for lime in the timothy crop has been greater, and the percentage gain nearly as great as in the clover, and in both it has been much greater than in the oats or wheat, notwithstanding the fact that these crops have been grown at an earlier period after the liming than the clover and timothy.

THE FINANCIAL OUTCOME

Table VI gives the total value of all the crops for each rotation for the limed and unlimed land, the value of the gain for lime and that of the increase from the fertilizers, rating corn at 40 cents per bushel, oats at 30 cents and wheat at 80 cents, with stover at $3.00 per ton, straw at $2.00 and hay at $8.00.

As shown by this table, on the unlimed land the total value of the 5 crops of the rotation has amounted to $49.40 for the average of the unfertilized land and to $67.80 for the land receiving acid phosphate only, but the value of the increase on this land over the neighboring unfertilized land has been $17.81, because of the fact that the increase is calculated, not on the average of all the unfertilized plots, but on those nearest the treatment under consideration.

When the land has had lime in addition to the phosphate, the yield has run to $81.80 in value, or $14.00 more than that of the unlimed land, while the increase from the fertilizer has amounted to $21.52, making a total gain for lime and fertilizer of $35.52.

The addition of muriate of potash to the fertilizer has increased the total value of the crops to $76.28 on the unlimed and to $92.33 on the limed land, the gain for the fertilizer being $26.38 on the unlimed, and $30.95 on the limed land; the gain for lime alone being $16.05 and that for lime and fertilizer amounting to $47.00

When nitrogen in sulphate of ammonia has been added to this combination of phosphorus and potassium, the phosphorus being increased by 50 percent, the value of the produce has been $80.04 on the unlimed land and $104.15 on the limed land. Comparing with the neighboring unfertilized land, we find that this combination has increased the yield by $31.15 on the unlimed, and by

TABLE VI: Average value of crops for one rotation and value of increase for lime and for fertilizers.*

Treatment (Fertilizers per acre for each rotation)	Plot No.	Value per acre of total crops: Unlimed	Value per acre of total crops: Limed	Value of gain for lime	Value of increase from fertilizers: Unlimed	Value of increase from fertilizers: Limed
I: With nitrogen:						
Phosphorus, 20 lbs., in acid phosphate	2	$67.80	$81.80	$14.00	$17.80	$21.52
Phosphorus 20 lbs., potassium, 108 lbs. in muriate of potash	8	76.28	92.33	16.05	26.38	30.95
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	87.76	104,49	16.73	40.96	45.47
" " linseed oilmeal	21	82.20	99.82	17.62	35.61	39.04
" " dried blood	23	80.40	99.71	19.31	33.18	39.04
" " sulphate of ammonia	24	80.04	104.15	24.10	31.15	42.02
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs., and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	93.83	103.16	9.33	44.52	43.16
" " bonemeal	26	87.60	100.90	13.30	36.52	37.31
" " dissolved boneblack	27	87.28	100.81	13.53	35.70	37.24
" " basic slag	29	92.36	96.59	4.23	40.25	32.05
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	92.87	106.13	13.26	43.95	46.17
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus 48 lbs., and potassium, 112 lbs	18	99.08	115.05	15.97	51.09	53.56
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs	20	78.58	94.49	15.91	30.96	32.12
Average unfertilized yield		49.40	61.40	12.00	.....	.....

*Valuations: Corn, 40 cents per bu.; oats, 30 cents; wheat, 80 cents; hay, $8.00 per ton; stover $3.00 and straw $2.00.

$42.02 on the limed land. In other words, the fertilizers alone have increased the yield by $31.15 and the fertilizers and lime have increased it by $66.12.

When nitrate of soda has been substituted for sulphate of ammonia as the carrier of nitrogen the increase from the fertilizers has been nearly $10.00 greater on the unlimed land, and $3.45 greater on the limed land than that produced by the combination carrying its nitrogen in sulphate of ammonia.

The combined increase from lime and fertilizers carrying nitrate of soda has averaged $62.19, and that from lime and fertilizers carryng sulphate of ammonia has averaged $66.12; the total yields, however, have had the same value, within a few cents, indicating that the higher increase found after sulphate of ammonia in this case has been due to a lower rate of yield of the unfertilized land.

Where the nitrogen has been given in organic form, in linseed oilmeal or dried blood, the increase on the unlimed land has been a little greater than that from sulphate of ammonia, but on the limed land the sulphate of ammonia has produced the greater increase.

In the case of carriers of phosphorus, basic slag seems to have been a little less effective than acid phosphate on unlimed land, while on the limed land acid phosphate has produced a decidedly greater effect than the slag, the difference amounting to ten dollars for each rotation. In comparing these phosphates the total phosphorus in basic slag has been set against the available phosphorus in acid phosphate. Even on this basis the cost of a pound of phosphorus is usually a little greater in basic slag than in acid phosphate.

The value of increase from fertilizers is $3.66 greater on the unlimed half of Plot 11, receiving for each rotation 480 pounds of nitrate of soda and 320 pounds of acid phosphate, than on Plot 17, receiving 240 pounds of nitrate of soda and 480 pounds of acid phosphate, but the fertilizers for Plot 11 have cost $5.90 more than for Plot 17. On the limed half the increase on plot 17 is greater than on Plot 11. The still larger application of nitrate of soda, on Plot 12, fails to meet a corresponding response in increase of crop. Evidently, so far as this soil and these crops are concerned, the ratio of nitrogen to phosphorus has been more effective on Plot 17 than on either Plot 11 or Plot 12.

In Table VII is shown the cost of treatment and the net gain per acre for the limed and unlimed land for each rotation, the cost of liming being estimated at five dollars per acre, and the nitrogen and phosphorus in other carriers being computed at the same cost as in nitrate of soda and acid phosphate, except in the case of manure,

TABLE VII: Cost of treatment and net gain per acre

Treatment	Plot No.	Cost of treatment*		Net gain per acre	
		Unlimed	Limed	Unlimed	Limed
I: Without nitrogen:					
Phosphorus, 20 lbs. in acid phosphate	2	$ 2.60	$ 7.60	$15.20	$24.20
Phosphorus, 20 lbs., potassium, 108 lbs. in muriate of potash	8	9.10	14.10	17.28	28.33
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.					
Nitrogen in nitrate of soda	17	17.60	22.60	23.46	35.09
" " linseed oilmeal	21	17.60	22.60	18.01	30.63
" " dried blood	23	17.60	22.60	15.58	29.89
" " sulphate of ammonia	24	17.60	22.60	13.55	32.65
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs., and potassium, 108 lbs.					
Phosphorus in acid phosphate	11	23.50	28.50	21.02	25.35
" " bonemeal	26	23.50	28.50	13.02	21.32
" " dissolved boneblack	27	23.50	28.50	12.20	20.73
" " basic slag	29	23.50	28.50	16.75	15.98
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	30.70	35.70	13.25	21.51
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus 48 lbs., and potassium, 112 lbs	18	32.00	37.00	19.09	35.06
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs.	20	16.00	21.00	14.96	25.87

*Valuations: In fertilizers, phosphorus, 13 cents per lb.; potassium, 6 cents; nitrogen, 19 cents. In manure, nitrogen is computed at 15 cents and phosphorus at 7½ cents—the approximate cost of these elements in tankage and fine bone as estimated in the Official Report on Commercial Fertilizers for 1913, of the Agricultural Commission of Ohio.

where the nitrogen is estimated at 15 cents and the phosphorus at 7½ cents per pound, following the valuation for these elements in tankage and fine bone in the Official Report on Commercial Fertilizers for 1913 of the Agricultural Commission of Ohio. At these valuations a ton of yard manure would be worth two dollars, and the outcome shows that, when supplemented by liming, the yard manure has produced a very profitable increase, although the gain per pound of fertilizing elements contained is not equal to that from the best proportioned chemical application. Other experiments* have shown that before we can expect to realize the full effect of manure we must re-enforce it with some carrier of phosphorus, and must avoid the wastes which occur in the ordinary barnyard.

CONCLUSIONS

The experiments reported in this bulletin show that on soils deficient in lime it is as necessary to make good this deficiency as it may be to make good that of nitrogen, phosphorus or potassium. They show, moreover, that lime does not take the place of other fertilizing elements, but only accomplishes its full effect when used in connection with liberal manuring or fertilizing.

WHAT IS LIME?†

Everyone who has handled a lump of quicklime has noticed that it is much lighter in weight than an unburnt limestone of equal bulk. This means that one of the materials of which the original stone was composed has been driven off from the stone by the burning, and has escaped as an invisible gas into the atmosphere. This gas is carbon di-oxide (di meaning two) the "carbonic acid gas" of the older chemistry. It is the same gas which is breathed out of the lungs, and if we pass our breath through a tube into the bottom of a tumbler of limewater a white cloud will be formed by the union of the carbon di-oxide of the breath with the lime dissolved in the water, thus reversing the results attained by burning; for the white cloud in the tumbler and the limestone in the quarry are both the same substance, namely; carbonate of lime.

If we first thoroughly dry a pure limestone and then burn it, we shall find that it has lost about 44 percent of its original dry weight. That is, 100 pounds of pure, dry limestone, or carbonate of lime, will produce about 56 pounds of lime. But what is lime?

*See Bulletin 183 of this Station.

†From the Official Report for 1913 on Commercial Fertilizers and Agricultural Lime of the Agricultural Commission of Ohio.

CALCIUM

The chemist is able to separate the burnt lime into two constituents, one of which again is the oxygen gas which constitutes about one-fifth of the air we breathe, while the other is a brilliant, light yellow metal called calcium, which rapidly tarnishes when exposed to moist air by recombining with oxygen and returning to lime. This elementary metal, calcium, is the essential constituent to which lime owes its peculiar properties. Oxygen and carbonic acid may be found in thousands of other combinations which have none of the characteristics of lime and perform none of its functions. We use lime, therefore, simply as a convenient carrier of calcium.

HYDRATED LIME

If we expose a lump of freshly burnt lime to ordinary moist air, in the course of a few days, or weeks, depending largely upon the amount of moisture in the air, it will be found to have crumbled into a fine powder. In other words, it is air slaked. We may accomplish this result much more quickly by pouring water on the lump of lime, when it will fall to powder before our eyes, and with the evolution of considerable heat, thus showing that a chemical operation has taken place, in which the water has become chemically combined with the lime; for, unless excess of water has been used this powder will be just as dry to our senses as the original quicklime. This combination of lime with water is called hydrated lime, and if we weigh the powder resulting from either air slaking or water slaking we will find it to be about one-third heavier than the original quicklime from which it was produced, this additional weight being due to chemically combined water.

ATOMIC WEIGHTS

Chemists have found that elementary substances, such as calcium, carbon, oxygen and hydrogen always combine with each other in certain fixed weights, or multiples of such weights, which are called atomic weights, or combining weights; and hydrogen, which is the gas which causes balloons to rise, and is the lightest of known elements, is taken as the unit of weight. (The reason balloons rise is that hydrogen is lighter than air, not that hydrogen has no weight of itself; just as wood floats upon water because it is lighter than the water. If hydrogen be placed in a vacuum it will fall, instead of rising, just as wood falls in air.)

Measured by hydrogen as unity, the other elements which enter into the composition of lime in its various forms have the following atomic weights:

Calcium (Ca)	40
Oxygen (O)	16
Carbon (C)	12
Hydrogen (H)	1

CHEMICAL SYMBOLS

In order to save space and time each element is given a symbol to designate it, these symbols being usually the first one or two letters of the name of the element, and the symbols of the elements under consideration are as given above in parentheses. In designating chemical compounds these symbols are so used as to show not only the elements contained but the proportion of each element in the compound: Thus water, which is a chemical combination of two combining weights of hydrogen with one combining weight of oxygen, has the symbol H_2O, which means that in 18 pounds of water 2 pounds are hydrogen and 16 pounds are oxygen; but 2 is approximately 11 percent of 18, and 16 is about 89 percent of 18, so we say that water is 11 percent hydrogen and 89 percent oxygen.

The symbol for lime is CaO, meaning that 40 pounds of calcium are combined with 16 pounds of oxygen in every total of 56 pounds; or 71 percent of calcium and 29 percent of oxyge

The symbol for carbon di-oxide is CO_2, meaning that one combining weight of carbon is united with two combining weights of oxygen, or 12 parts by weight of carbon with 32 parts by weight of oxygen, so that this gas is a little more than 27 percent carbon and a little less than 73 percent oxygen.

In carbonate of lime we have three elements to consider: calcium, carbon and oxygen, and the symbol of this compound is CaO, CO_2 or $CaCO_3$, so that in a given weight of pure limestone we would have for every 40 pounds of calcium 12 pounds of carbon and 48 pounds of oxygen. The sum of these weights is just 100, so that 100 pounds of carbonate of lime contains 40 percent calcium, 12 percent carbon and 48 percent oxygen.

Hydrated lime has the symbol CaO, H_2O or CaH_2O_2, so that in a given weight of hydrated lime the elements would have the ratio 40:2:32, or 54 percent calcium, 2.7 percent hydrogen and 43.3 percent oxygen.

RELATIVE VALUE OF CALCIUM CARRIERS

Now let us see how much actual calcium we shall find in a ton of each of the different carriers mentioned:

Carrier	Symbol	Percentage composition				Pounds Calcium in one ton
		Ca.	O.	C.	H.	
Quicklime	CaO	71	29	..	...	1,420
Hydrated lime	CaO, H_2O	51	43.4	..	2.7	1,080
Carbonate of lime	CaO, CO_2	40	48	12	...	800

One tonof quicklime carries 1,420 pounds of calcium. To carry this quantity of calcium in hydrated lime would require as many hundred pounds of hydrated lime as 54, the quantity of calcium contained in 100 pounds of hydrated lime, is contained in 1,420 which is 26.3. It will therefore take 2,630 pounds of hydrated lime to carry as much calcium as is found in 2,000 pounds of quicklime. In the same way it is shown that 3,550 pounds, or nearly 2 tons, of carbonate of lime will be required to carry the calcium found in one ton of quicklime.

THE CARBONATES OF LIME

Three forms of carbonate of lime are on the market: one produced by grinding raw limestone, one found in the beds of marl sometimes found under muck beds, and one resulting from manufacturing processes in which the carbonate is produced by chemical processes analogous to that which is witnessed when we breathe through a tube into a glass of limewater. This process, by which the carbonate of lime is precipitated, to use the chemist's term, results in a much finer powder than can be produced by ordinary grinding, and hence a precipitated carbonate of lime may be more quickly available than ground limestone. In actual practice, however, the experiments made by the Ohio Experiment Station have shown no practical superiority of one form of lime over the other, provided the limestone has been so ground that 80 percent of it will pass through a sieve having 100 meshes to the linear inch, and provided also, of course, that the two materials are used on the basis of the actual calcium contained. As the outcome of these experiments the Experiment Station is using either one ton of quicklime or two tons of ground limestone per acre, which ever can be spread on the field in these quantities for the least money.

To illustrate this point, let us suppose that ground limestone and quicklime are offered at the same point of shipment at $1.25 per ton for the former and $5.00 for the latter. Let us assume that the freight will be $1.50 per ton, and the cost of hauling from the car and spreading $1.00 per ton. Our account will then stand as follows:

	Quicklime *1 ton*	*Ground stone* *2 tons*
Cost at point of shipment	$5.00	$2.50
Freight	1.50	3.00
Hauling and spreading	1.00	2.00
Total	$7.50	$7.50

ADULTERATED LIMES

A factor which is not taken into the above account is the greater discomfort in handling the quicklime than the ground stone. Moreover, sometimes, the so-called "agricultural lime" is suspected to

contain more or less unburnt stone, ashes, etc., accumulating at the bottom of the kiln, which are ground up together. Such lime, of course, would not be pure quicklime, and a very little adulteration of this sort would bring the value of the one ton of "agricultural lime" much below that of the two tons of limestone. On the other hand,. the ground stone is not always so finely ground as it ought to be to produce the best results, and it may sometimes be ground from rock containing sand or earth, although this probably is seldom the case, for when a product is worth only about a dollar per ton there is less inducement to adulterate it than when the price is higher.

MAGNESIA

Magnesia (MgO) is the oxide of the element magnesium, which is very similar in its characteristics to calcium, and the two are generally found associated in ordinary limestones. Magnesium has a somewhat greater effect than calcium in correcting acidity, 84 pounds of magnesium carbonate being equivalent in this respect to 100 pounds of calcium carbonate. Within certain limits the presence of magnesium in the limestone, therefore, is an advantage; but when used in excess magnesium may cause injury rather than benefit—which is also true of calcium, or any other good thing. The difference between magnesium and calcium in this respect is that it requires a smaller amount of the former than of the latter to cause injury. Such injury is more liable to follow the use of a magnesium lime, carrying magnesia in the caustic form, than when the carrier is in the carbonate form.

When the limestone carries nearly as much magnesium as calcium it is called a dolomite, and the use of quicklime made from such a stone might be questionable; when, however, the magnesia does not reach more than 25 to 30 percent in the lime there is but little danger of injury from it on ordinary Ohio soils, if applied at the usual rate of about a ton to the acre once in 4 or 5 years. There is but little danger from magnesia in the carbonate form.

THE CHIEF THING TO REMEMBER ABOUT LIME

The chief thing to remember about lime is that it is the natural calcium and magnesium carbonate which we find in limestone that does the work we want done in the soil, whether in feeding the plant or in neutralizing soil acidity, and that whatever be the carrier we may use, whether quicklime or hydrated lime, it will be quickly changed to the carbonate by the moisture and carbon di-oxide of the soil, and that the only reasons for using any other carrier than the natural carbonates are to secure the greatest fineness of division and to save freight and labor in handling.

WHEN TO USE LIME

Half the soils of Ohio—covering the region west of a line drawn from Sandusky through Columbus to the west line of Scioto county, excepting Williams and Fulton counties and adjoining portions of Henry and Defiance counties—lie over limestones. In this region there may be old fields in which the supply of lime in the plowed surface has become deficient, but as a rule the expense of a general application of lime should not be incurred until a preliminary test has been made. Such a test is best made by liming a narrow strip across a field and observing the effect on the clover crop. For such an experiment common hydrated or builder's lime may be used at the rate of 15 to 20 pounds per square rod or 2,000 to 3,000 pounds per acre

At the Experiment Station the best results have followed when the lime has been applied to the surface while the land was being prepared for corn, the cultivation of the corn crop and the subsequent plowings mixing the lime through the seed bed so thoroughly that when the clover crop has come along in its regular place in the rotation it has found the soil acidity thoroughly corrected.

THE LITMUS TEST

The litmus test is a simple chemical test for soil acidity, made by inserting a strip of blue litmus paper in moist soil and letting it stand for a few minutes. If the soil is acid, the paper will turn distinctly red. As the paper may sometimes be reddened by temporary conditions of acidity the actual application of lime as above described is much the better test. Litmus paper may be procured at most any drug store.

When lime is needed it should be applied in sufficient quantity to accomplish its work. At the Experiment Station the rule is to apply one ton of quicklime, 1⅓ ton of hydrated lime, or two tons of carbonate of lime per acre as a first application, this to be followed every four or five years thereafter—or every time the corn crop comes around in rotation—by half the above quantities.

Lime cannot be satisfactorily applied with the ordinary fertilizer drill, as it does not sow enough and will not feed slaked lime regularly. Several good lime spreaders are now on the market.

While, as above stated, the need for lime is doubtful over the western half of the state, the case is very different over a large part of eastern Ohio, where the rock floor is made up of shales and sandstones. At the Experiment Station lime is adding six to eight bushels of corn to the acre, two or three bushels each of oats and wheat, and is more than doubling the clover crop.

The Ohio Agricultural Commission has been authorized by law to extend to the trade in agricultural lime the same control now exercised over that in fertilizing materials.

WHAT CROPS TO LIME

In the experiments reported in this bulletin the lime has been applied to corn, in a 5-year rotation of corn, oats, wheat and clover, the lime being spread on the surface and harrowed in after plowing the land, and the outcome seems to have abundantly justified this practice. Many farmers, however, prefer to apply the lime when preparing for wheat, because the rush of work is not so great at that season and because the roads are usually in better condition then for hauling the lime.

Reference to the preceding tables will show that if we should take the average gain for lime on the land receiving the complete fertilizer carrying 30 pounds of nitrogen—Plots 17, 21, 23 and 24—and were to value corn with its stover at half a dollar per bushel, oats with its straw at one-third of a dollar, wheat with its straw at 90 cents and hay at $8.00 per ton, we would have the following as the value of the increase in the different crops due to the liming:

	Increase	Value
Corn, bus	10.25	$5.12
Oats, bus	1.70	0.57
Wheat, bus	3.53	3.18
Clover hay, tons	0.66	5.28
Timothy hay, tons	0.735	5.88
Total		$20.03

On these valuations the greatest gain from the liming has been found in the timothy crop, while the clover and corn have shown a nearly equal gain.

Attention has been called to facts which seem to indicate that a large part of the increase following lime should be ascribed to its action in favoring nitrification, but if it is to serve this purpose effectively it must be incorporated with that stratum of soil in which the nitrifying organisms perform this service and which is the same stratum in which the roots of corn and other crops find their sustenance; for the nitrifying organisms are living plants, whose existence depends upon the same conditions of moisture and air circulation required by corn roots. It the corn roots are exposed to free circulation of air they quickly perish; but they also perish if deprived of air for any length of time, as by being covered with water. Moisture is essential to their life, but an excess of water is fatal, because it excludes the air.

In one respect the corn roots have the advantage of the nitrifying bacteria; they may travel considerable distances in search of food, being connected a' all times with s base of supplies in the stalk, from which they are pushed forward, but the bacteria have no

such support, each minute organism being independent of all others and dependent solely upon the means of subsistence with which it finds itself in contact.

If, therefore, lime is to perform its full function in the soil it must be distributed throughout that layer of the soil which contains the necessary conditions of moisture and air circulation for the growth of crop roots, and must be so distributed that a particle of lime may be found in contact with every particle of soil.

When the lime is reduced to a fine powder, as by burning and slaking, or by grinding, and is then stirred into the surface of a plowed field the first steps have taken for its most effective service. The further stirrings which take place in the cultivation of the corn crop and in the plowings for the oats and wheat crops produce a still more intimate admixture of the particles of lime and soil, so that by the time the clover seeds are sown the conditions are as favorable as we can make them.

To delay the liming until the land is being prepared for wheat means a much less perfect mixture of lime and soil than results from liming the corn crop, and consequently a less perfect utilization of the lime by the clover, although it is much better to lime the wheat crop than not to lime at all.

It is sometimes asked whether the final outcome will not be the same, after a system of liming is established, whether the lime is put on the wheat or corn. The reply is that the necessity for repeating a dressing of a ton per acre of lime or limestone every four or five years means that much of the lime is lost, whether by being dissolved and carried into the drainage waters, or by being fixed in unavailable form; for the consumption of lime as plant food is comparatively insignificant, as shown by the table below, giving the calculated amounts of lime carried off the land by the average crops grown on the limed ends of Plots 17, 21, 23 and 24 in the experiments above described:

Crop	Average yield per acre		Pounds of lime (CaO)	
	Grain bus.	Stover, straw or hay lbs.	In grain	In stover, straw or hay
Corn	57.18	2.658	0.96	14.24
Oats	49.73	2.574	1.75	12.87
Wheat	27.82	2.876	0.83	7.76
Clover	....	3.815	....	76.30
Timothy	....	4.514	....	14.40

A total of 129 pounds of lime, equivalent to less than 250 pounds of limestone. Experiments have shown, however, that we never recover in the increase of crop more than 60 to 80 percent of the phosphorus or potassium given in fertilizers or manure, and the

same principle no doubt applies to the recovery of lime, so that it is probable that an annual application of 80 to 100 pounds of limestone would be required to replace that taken off by such crops as those grown in these experiments. But experience has shown that the chief purpose of liming the land is not to supply lime as plant food, but to promote nitrification and to correct soil acidity, and for these purposes the lime must be used in much larger quantity than would be required were its function limited to the direct feeding of the plant.

In performing these functions the lime enters into combination with the soil acids, forming neutral salts, some of which are soluble and are carried into the drainage waters. In the case of the cereal crops the chief function of lime is apparently to favor the action of the nitrifying bacteria, through whose agency the nitrogen held in the remains of previous vegetation is made available, probably in the form of nitrate of lime. Thus we see that Plot 8, which receives phosphorus and potassium, but no nitrogen, produces less grain on the unlimed land than any of the plots which receive the same quantity of phosphorus and potassium with nitrogen in addition. When lime is added, however, Plot 8 produces more corn than any of the plots which receive nitrogen but no lime, although on the limed land the addition of nitrogen to phosphorus and potassium causes a further increase in yield. In the oats crop the effect of lime is too small to justify definite conclusions. In the wheat crop the increase from lime is smaller than that from nitrate of soda, but greater than that from other carriers of nitrogen, thus indicating that much of the effect of lime is due to the making available of organic and ammonia nitrogen.

In the clover crop nitrogen produces no increase on the unlimed land when given in other carriers than nitrate of soda, and the increase from this salt is apparently due to the sodium, rather than to the nitrogen contained.

These facts seem to justify the conclusion that the lime applied to the corn crop in liberal quantity has encouraged the production of nitrates for several succeeding crops, and has furnished a sufficient quantity of alkaline base to neutralize any excess of nitric acid produced, beyond the capacity of the crops to utilize it, and thus has prepared a neutral soil in which the clover has found the conditions essential to its full development.

The increase in the timothy crop may be accounted for in part in the advantage gained by its association with clover, but the darker color of the timothy growing on limed land is evidence that it is having access to a larger supply of nitrogen than is found in the unlimed land, thus again suggesting that much of the effect of lime is due to its forwarding of nitrification.

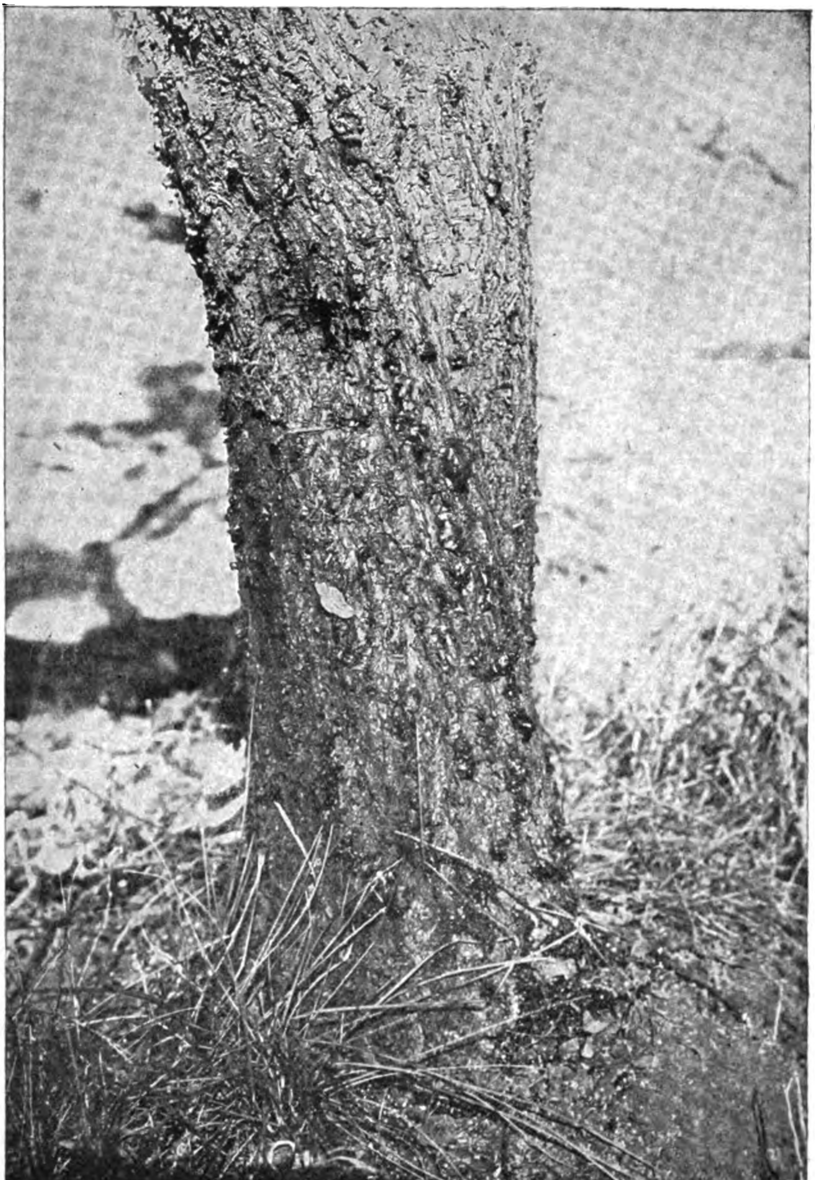

Plate III. Gumming from attack of Fruit Bark Beetle on trunk of old tree.

At the point where the entrance burrow meets the sapwood the chamber bends upward and extends approximately parallel to the axis of the trunk or branch in which it is made, and may reach a length of two inches or more, but the usual length lies between ½ inch and 1½ inches. The average length is very close to 1 inch. Where work is continuous, from 7 to 10 days seems to be about the time necessary to complete the chamber, but it is often, perhaps even generally the case, that the work is not continuous but intermittent, and that an indefinite, but longer period than the one just stated, is required.

Mating Habits: As soon as the female has lengthened her burrow enough to permit the entrance of her whole body, she ceases work long enough to accomplish mating. A male may be in waiting at the mouth of the burrow, in which case copulation occurs at once, or it may occur even before the female has excavated enough burrow to receive her body, or sometimes before she has commenced any burrow at all. Usually, however, the female ceases work and protrudes the end of her body from the entrance, and thus awaits the male. Copulation then takes place with the male outside the burrow and the female within it. In other cases mating is performed with both insects inside the burrow, with only the head of the male projecting. The only copulation that was timed required 20 minutes for its completion. The males can often be observed waiting for hours at a time at the entrance to the brood chambers. They seem to become restless at times and enter the burrow for a short distance and then back out. In a breeding jar, 19 males were counted on a single branch, all waiting at the same time at the entrances to the brood chambers in the bark. A number of these chambers were opened and found to contain female beetles, eggs, and very young larvae. Sometimes one male will drive another away from the entrance at which he is waiting. It seems probable that mating takes place several times during the construction of the brood chamber, and the length of the brood chamber and the number of eggs and larvae produced by the female may, perhaps, depend on the number of matings experienced in her lifetime.

Egg-laying and Galleries of the Larvae: Egg-laying or oviposition occurs soon after mating. The female commences the excavation of the brood chamber proper after copulating, the floor of it in the bast or sapwood, and the roof in the bark. Small niches or cells are made along the side walls, half in the bast and half in the bark; each is just large enough to receive an egg. After many attempts, Mr. J. L. King was fortunate enough to observe one female in the act of oviposition. The brood chamber had been opened by means of a sharp knife and a small flap of bark was lifted from the top of the brood chamber. A tiny egg-niche had been

made by the beetle before the burrow was opened. After some hesitation the beetle backed out of the burrow to the outside where she immediately turned about and backed into the brood chamber. Upon reaching the locality of the niche, she distended her abdomen and with it seemed to be feeling along the wall of the burrow as if hunting for the niche. After a few moments of exploring the niche was located. The tip of the abdomen was then held within the niche and a single tiny, translucent egg was deposited therein and left standing at right angles or endwise to the burrow. The beetle then crawled out of the burrow and entered again, head first, and upon reaching the niche she covered the egg with fine frass. The mouth-parts seemed to be used to cover the eggs; after covering them over the insect remained quietly within the burrow. There are two lines of eggs, one on each side of the burrow; the eggs are sometimes almost touching each other. The egg-lines extend backward into the burrow until the last eggs laid are practically out to the terminal corner of the burrow. It would be impossible for the female to place these newest eggs in position without backing into the burrow to do it. The frass-packing over the eggs practically makes an inner smooth tube in which the adult lives while the eggs and young are without. Each young larva commences the construction of a gallery outward from the brood chamber soon after it

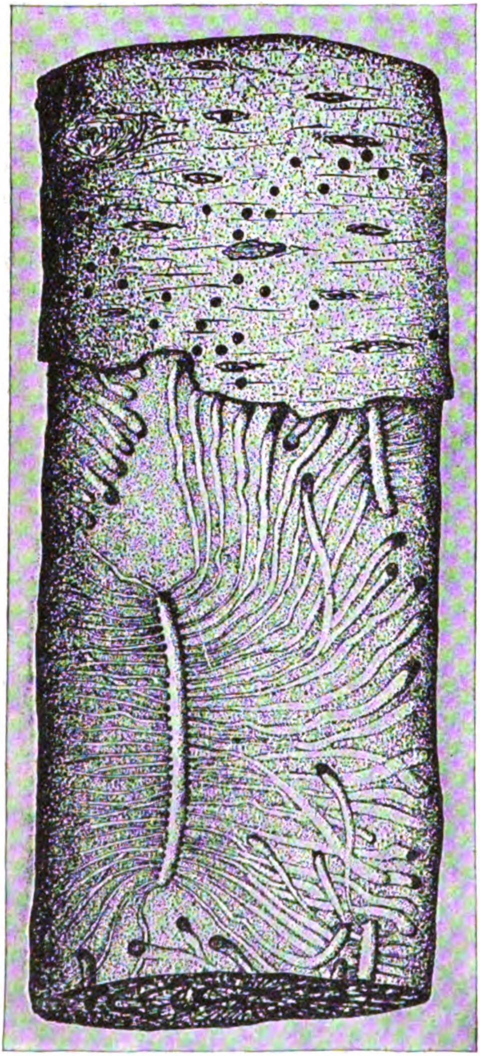

Fig. 3. Brood chamber and galleries of the Fruit Bark Beetle, *E. rugulosus*, natural size.

hatches, generally extending it at a right angle if near the middle of the chamber, and somewhat obliquely outward if originating near its end. The galleries diverge more and more from each other as they are enlarged in diameter, to accommodate the growing grubs. The general form of the completed burrow with its finished radiating galleries is shown in the accompanying drawing. (Fig. 3.) The flooring of the galleries, like that of the main chamber, lies in the sap-wood while the over-head roof is in the bark. These galleries are completely filled with a reddish-brown frass or excrement, derived from the bark. They vary in length from less than an inch to three or four inches or more in length, depending on the kind of wood used for incubation, and also on the crowding of the galleries, the meeting with obstructions or with old galleries of earlier generations, etc. The same area may be crossed and intercossed by the galleries of several different brood chambers. In cases of bad infestation the bark over the whole trunk and larger limbs may be so loosened that it falls away, or may be torn away by woodpeckers searching for the grubs, leaving the inner wood exposed and bare. Such an infestation means the speedy death of the tree, if it occurs in living wood. The areas generally chosen are dead or diseased patches of bark on otherwise healthy trees, or else the trunks and branches of weak and unhealthy trees. Egg-laying begins as soon as the burrow reaches the sapwood in case of those females which have mated, while some burrows from 3/8 to 1/2 inch long do not contain eggs, though females may be present. These females probably have not yet mated. The number of females appears to greatly exceed the number of males.

The period of incubation, so far as could be determined, is from 3 to 4 days. Of 7 eggs, laid in July and kept under observation, 3 hatched in 4 days and the remaining 4 in 3 days. The number of eggs deposited by one female in one brood chamber ranges from 20 to 163 or more. From counts made on 19 brood chambers, June 26, 1908, the minimum number was 30, and the maximum 112, the average 76. June 29, 1908, counts were made on 8 brood chambers and the minimum number of eggs found was 47, maximum 132, average 91. Counts taken on earlier dates gave smaller numbers, presumably because not all of the eggs had yet been laid. The earliest date of discovery of eggs in 1908 was June 7, but young larvae were found May 28 in 1912, indicating that egg-laying may commence about the 20th to the 25th of May in some seasons.

The entrance to old burrows is quite generally plugged with the body of the dead female. Whether she comes to the entrance to obtain fresh air when she is finally exhausted and life is flickering out, or whether she instinctively devotes her carcass as a protection against the entrance of parasites into the burrow can be only a matter of speculation.

FIRST GENERATION OF LARVAE

The newly hatched larvae are only about .55mm. long. Soon after the commencement of feeding a pinkish tinge overspreads the body due to the bark which they eat.

In 1908, the first larvae produced by the first brood of beetles were found June 13th. One larva was at this time 1-4 inch away from the burrow. Fourteen very young larvae were found to have hatched in the same burrow on this date. The larvae had become numerous by the end of June. They could be found from this time on until winter, because of some overlapping of the first and second broods.

In 1912, some larvae hatched May 28 and were full grown July 3, a period of 36 days being required to reach maturity. Another lot, hatching June 5, matured July 7, or within 30 days. When full grown, the larvae form pupal chambers at the ends of the larval burrows. These pupal cells are formed in the sound sap-wood just beneath the bark and are just deep enough to conceal the larvae. The entrance into these oval cells is plugged with sawdust or frass, having the inner portion of the plug very compact, the small particles being apparently gummed together by a secretion from the larva. After finishing the cell, the larva turns about and rests with its head toward the plug or cell-opening in which position it pupates, ready to bore through the bark to the outside as soon as it becomes adult.

Measurements in millimeters taken of a series of larval heads and mandibles indicate the probability of four stages or instars in the larval life as shown by the following table:

TABLE I. Showing measurements of the instars.

First instar			Second instar			Third instar			Fourth instar		
Length of head	Width of head	Width of mandible	Length of head	Width of head	Width of mandible	Length of head	Width of head	Width of mandible	Length of head	Width of head	Width of mandible
.26	.20	...	.36	.32	.12	.52	.48	.20	.72	.60	.28
.28	.22	.08	.32	.28	.12	.48	.40	.20	72	.60	.24
.24	.24	.1	.36	.28	.12	.56	.50	.20	76	.64	.28
.26	.22	.08	.36	.30	.12	.42	.44	.20	.62	.54	.22
.28	.26	.12	.32	.28	...	.48	.44	...	.60	.50	.22
.28	.26	...	.30	.26	...	.38	.32	...	.64	.60	.24
.28	.24	.08	.32	.28	.12	.40	.36	...	.60	.52	.20
.28	.20	.08	.32	.28	.12	.48	.40	...	72	.64	.28
.24	.20	...	.36	.32	.12	.48	.44	.20	72	.64	.28
.26	.24	.12	.36	.32	.12	.56	.50	.22	.76	.72	.28
.28	.26	...	.32	.28	.12	.52	.50	.20	.60	56	.24
.26	.20	.08	.36	.32	...	.46	.36	.20	64	.56	.28
.28	.26	...	.36	.28	.12	.40	.36	...	.72	64	.28
.28	.24	...	.36	.32	.12	.44	.36	.20	72	64	.28
.28	.24	.08	.36	.32	.12	.44	.36	.20	76	66	.30
.28	.26	.08	.40	.36	.12	.44	.32	...	72	.64	.28
.28	.24	.08	...	...	...	.38	.32	...	72	.64	.28
.26	.24	...	...	...	...	...	...	...	...	...	...
.28	.26	.08	...	...	...	...	...	...	...	...	...
.24	.20	.08	...	...	...	...	...	...		...	...
Av. of 20 spec. .267mm.	Av. of 20 spec. .238mm	Av. of 13 spec. .087mm	Av. of 16 spec. .323mm	Av. of 16 spec. .30mm.	Av. of 13 spec. .12mm.	Av. of 17 spec. .461mm	Av. of 17 spec. .407mm	Av. of 10 spec. .20mm.	Av of 17 spec. 690mm	Av. of 17 spec. 608mm	Av. of 17 spec. 260mm

The individual measurements in nearly every case, as may be seen from an examination of the table, approximated some one of the averages closely enough to enable us to refer the specimen without much doubt to the corresponding instar as classified in this table.

MIDSUMMER BROOD OF PUPAE

As noted in the preceding paragraph, the pupal stage from the first generation of larvae is entered upon in early July or thereabouts. Since the pupal period for this season is generally from 7 to 10 days, or slightly more or less, the adults of the second brood begin to appear about the middle of July or a little earlier.

SECOND GENERATION OF ADULTS

We have already observed that there is some overlapping of the two generations of insects. The early beetles start about the middle of May, a few specimens coming earlier, and the brood is practically over by the middle of June, though a few females linger for nearly a month longer. When the males become aged and decrepit they drop to the ground and die, while the female dies, as a rule, resting in the mouth of her burrow. The second or summer brood of adults begins about the middle of July and they continue to issue until late August or early September. The accompanying curve (Plate IV), prepared by Mr. King, shows the rise and fall in numbers of the adults for the different dates of the season; the counts were made from specimens issuing from the laboratory breeding jars during the summer of 1912.

Beetles were found as late as Oct. 29, 1912, and were not infrequent in breeding cages until Oct. 19, 1908. Unhatched eggs could be found in the burrows until late in September, 1912, and larvae and pupae until late in October. These belated September eggs are presumably laid by stragglers of the second brood, though it is not impossible that they represented a partial third brood. Beetles emerging later than September have not been found laying eggs, and since no other stage than larvae can be found in northern Ohio during the winter or early spring, we are obliged to conclude that in all probability these late issuing beetles perish upon the coming of cold weather without reproducing.

HIBERNATING LARVAE

Most of the larvae must have been full fed at the outbreak of winter and made cells in the sapwood, then sealed themselves in by stopping the burrow connection with a cap of compact frass. They were thus in position to pupate and bore out through the bark as adults during the following May and June.

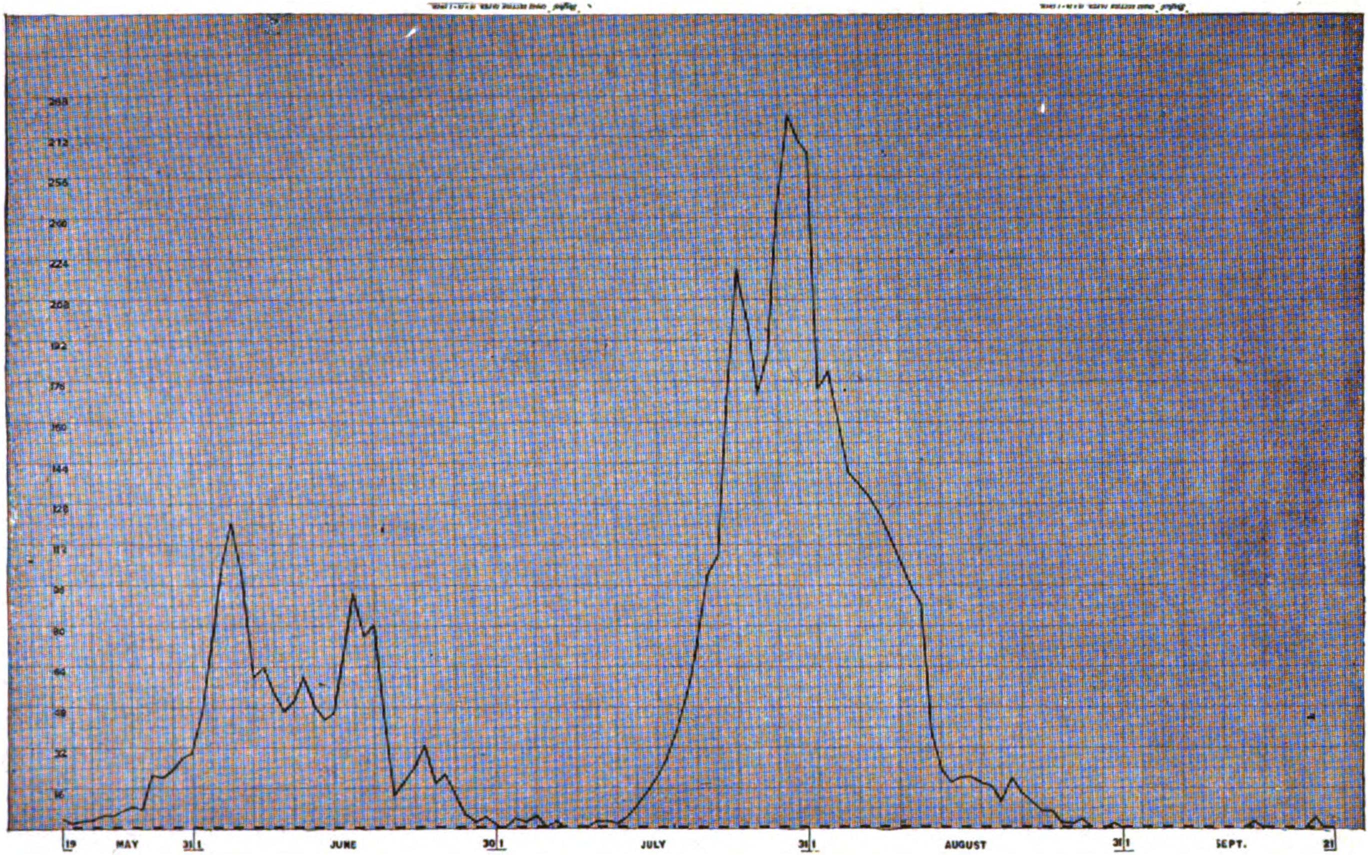

Plate IV. Curve showing rate of emergence of Fruit Bark Beetle, *E. rugulosus*, during summer of 1912. One small square upward represents one beetle emerging in the observation breeding cage and four squares longitudinally represent one day. The first brood is seen to be at its climax about the 5th or 6th of June and the second about the 29th or 30th of July.

Some of the larvae are found under the bark, and these probably feed until they become torpid and, as recorded at the beginning of the life cycle, they resume feeding in the spring. The record of the life cycle is herewith completed and connects back with the paragraph on "Hibernating Larvae," page 11.

CHARACTER OF INJURY

Reference has already been made in the "Introduction" and also in the paragraph on "Brood Chambers" to the general and also to some of the particular phases of injury caused by this bark beetle. Generally speaking, the beetles confine their attack during the early part of the summer, from May until late in June, to winter-killed and dying trees. The winter of 1911-12 was very severe throughout Ohio and many peach trees in the Lake District were weakened or killed. Many trees came into bloom and leaf, then withered and died. Trees in low, undrained orchards specially suffered, these, and also many that were weakened by the Peach Tree Borer, *Sanninoidea exitiosa*, dying. These dead and nearly dead trees formed the chief breeding places for the beetles. Attacks on such trees cause little or no gum flow. If sufficient life is still in the tree to cause an outflow of gum, very few of the brood chambers will be found to contain larvae. While larvae may sometimes be found in large numbers on living trees, close examination will show that they are located in a deadened or nearly dead area, and that few or none can be found where there is real live wood with sap coursing through it. However, if no damage at all were ever in any way inflicted upon living trees, the insect could not be classed as specially harmful. Vigorous, healthy trees are attacked by the adult beetles in late summer and fall, causing a copious gum flow and a gradual weakening. Entrance into the bark is nearly always made through the lenticels or through rough places and abrasions. From each hole exudes a quantity of gum which gradually accumulates outside. Where the beetles are exceptionally numerous, because of favorable breeding conditions in the neighborhood, and the supply of weakened trees has become exhausted, they may concentrate upon healthy trees to such an extent that these gradually become weak and furnish within one or two seasons a perfect condition for incubation. We have sometimes had reports of vigorous, healthy trees being killed outright in a few weeks by such onslaughts, but thus far have not been able to confirm the reports. However, we strongly suspect they are sometimes correct.

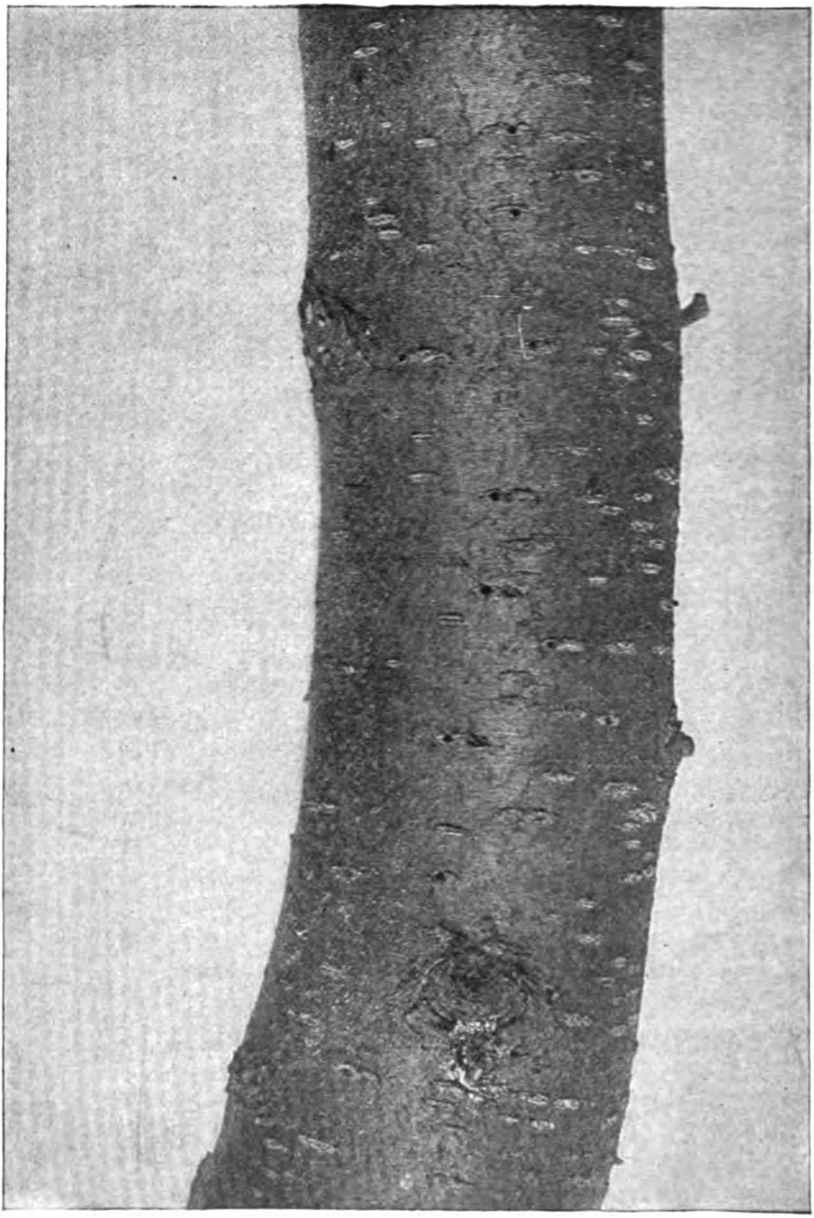

Plate V. Entrance holes of Fruit Bark Beetle, *E. rugulosus*, through lenticels and roughened places.

Plate VI. Gum exuding from feeding punctures of *E. rugulosus*.

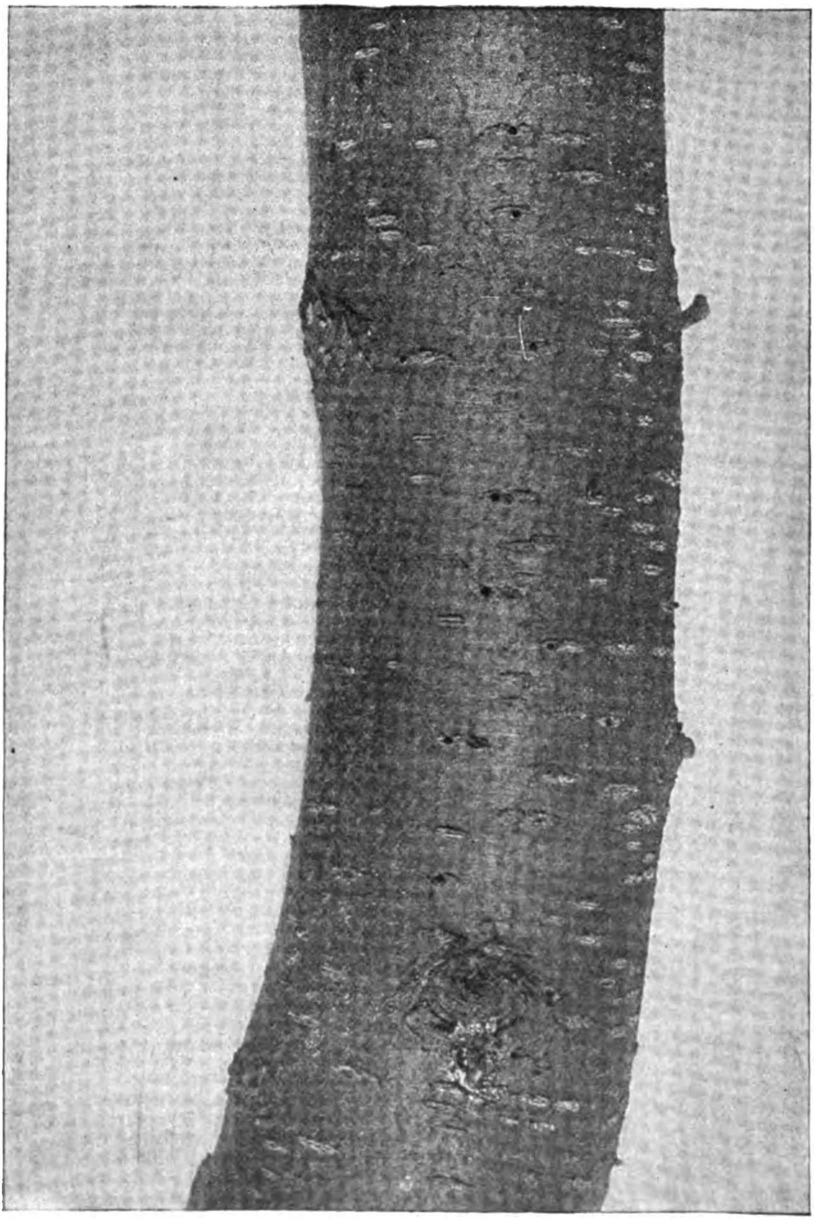

Plate V. Entrance holes of Fruit Bark Beetle, *E. rugulosus*, through lenticels and roughened places.

Plate VI. Gum exuding from feeding punctures of *E. rugulosus*.

In 1912, these attacks on living trees were first noted Aug. 14. The beetles were making these feeding chambers chiefly on branches two or three years old, and into the new twigs. On the twigs the beetles were boring shot holes in the crotches of the leaves and of the winter buds or in leaf scars. A few beetles could be found embedded in the exuded gum-drops like fossil insects in amber. Later in August more trees were found with the beetles at work on the trunks and larger limbs. Here, again, according to the seemingly invariable rule previously stated, the entrance holes were made through the lenticels and roughened spots on the bark. From such trees more than a gallon, in some cases two or three gallons, of gum would be adhering to the bark or collected into masses near the ground. Sometimes both *E. rugulosus* and *P. liminaris* are found working at the same time on the same trees.

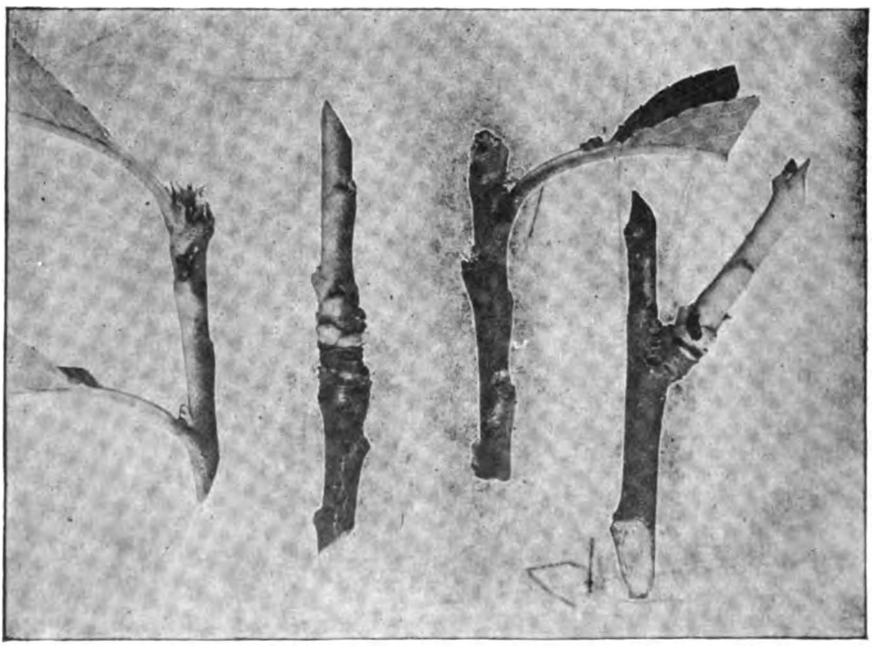

Fig. 4. Note beetles entering at bases of buds and in crotches of the leaves.

Under date of July 18, 1908, Mr. Wilson noted that all the dead and dying limbs of peach, plum and cherry were loaded with larvae, pupae, and beetles about to emerge. It was impossible to find wood with which to supply the breeding cages without cutting branches from perfectly healthy trees. One tree that was apparently in a healthy condition the preceding fall was attacked and then deserted

as the gum quickened its flow; it poured out through the holes as if through a strainer. Later, the same season, the beetles apparently made a second attack and completed the death of this tree. It is upon this instance as well as upon reports from correspondents, that we base our expressed opinion that perfectly healthy trees may sometimes be killed in a few weeks and before any brood chambers are constructed. July 30, 1909, Mr. L. L. Scott noted that "some of the weaker trees showed some beetles attacking them, notably on those parts of the trees which were partly dead or dying. On more healthy parts of the same trees the beetles had made their attacks, but in most instances, had been repulsed by the copious exudations of sap. Such attacks usually extend well into the tops and smaller limbs of the trees and, in several instances, the loss of sap was great enough to so weaken the trees that the egg burrows were completed without the beetles being driven out by the flow of sap. In all cases, only the weaker trees are attacked; those which are healthy and show a strong and luxuriant growth with smooth bark, are in no case to be found infested."

Fig. 5. Cage for confining beetles to trunk of a healthy tree.

Fig. 6. Interior of cage about healthy peach tree a few weeks after arranging. Note the dead wood piled at base and gumming of the trunk.

In order to test the foregoing question experimentally, Mr. King was instructed to construct a suitable cheesecloth cage about a vigorous, healthy tree and pile inside it large quantities of infested

wood so that the beetles, upon emerging, would be obliged to attack it in excessive numbers, both to obtain food and to oviposit, if oviposition were possible under such circumstances. Accordingly, July 13, 1913, a cheesecloth box-cage was constructed about the trunk and over some of the lower branches of a vigorous, healthy Elberta peach tree, the lower branches being cut square across at a uniform level to permit their being enclosed. The trunk passed out through the top-center of the cage and carried the larger part of the untrimmed top above the cage under ordinary normal conditions. Then at the base of the tree within the cage was piled a large quantity of dead wood containing larvae of *E. rugulosus*. The tree used was 8 or 9 years of age, about 10 feet high and had approximately 12 feet spread of top. It was in vigorous health. The cage was about 5 feet high, 3⅓ feet wide and 4½ feet in depth from front to back. The following notes record the result of the test:

"Aug. 7. Beetles emerging and attacking tree, always starting at pores in the bark. Weather very dry. Little bleeding at punctures.

Aug. 19. Beetles have attacked tree badly, causing a copious flow of gum from most all the lenticels, though the upper part of the tree shows no difference in color, nor any symptoms of a weakened condition.

Sept. 8. Though the tree has been badly bled, it no doubt will survive. The leaves on the small twigs in the enclosure have all been killed by beetles boring in at the base of the petiole, or behind the winter bud. No larvae were found within the tree. A few of the beetles oviposited in the dead wood which was left in the cage.

All the fruit ripened normally on the tree."

Though the result in this experiment was negative, we are not convinced that it is impossible for the beetles to kill healthy trees in a brief period. The fact that all small limbs and twigs within the cage died outright suggests that if the entire tree had been enclosed so that all the twigs and smaller limbs could have been attacked the whole top might have quickly succumbed. The purpose in enclosing only part of the tree and leaving most of the top outside the cage was to avoid complicating the questions of injury by shade and impeded circulation of the air with bark beetle damage.

The following quotations from other investigators are of interest in this connection:

Professor S. A. Forbes in his 15-17 Illinois Report (1885-90), pp. 1-12, says: "Two vigorous peach trees which showed the characteristic perforations very thickly placed, did not have the bark undermined, but these trees had bled very freely, the gum having run down the trunks to the ground in considerable quantities."

Again, in conclusion we note from Dr. Forbes: "Certainly, however, in Illinois, so far as one may judge from observations already made, plum and cherry trees which would pass as healthy, even those still young and thrifty, sometimes suffer serious injury. On the other hand, we have had occasional instances of a vigorous attack made on the trunk and branches of the peach which was apparently repelled by the great effusion of sap, so that no injury had resulted, except such as would follow from this profuse bleeding."

Mr. V. H. Lowe notes serious injury caused by *E. rugulosus* in 1899 in Bulletin 180, N. Y. Agricultural Experiment Station (Geneva, N. Y.), 1900. On page 122, Mr. Lowe notes injury to healthy cherry trees by the formation of round holes at the spur of the leaves. He states that one-fourth to about three-fourths of the leaves were dead, and that a fourth survey in the vicinity of Geneva, and in Monroe and Niagara counties, showed that this species had caused extensive injury during the season, then past, to healthy vigorous trees.

Dr. John B. Smith, in Bulletin 235, N. J. Experiment Station, p. 36, (1911), states the following concerning *E. rugulosus*: "It is an imported species and attacks almost all of our common orchard trees, boring into the bark to the bast and there making galleries in which the larvae develop. Perfectly healthy, vigorous trees are almost never attacked, and if entered by the beetle, the larvae do not find it possible to develop; but anything that serves to weaken or drain a tree, or make it temporarily less resistant, may serve to give these insects a foothold."

DISEASES RESEMBLING WORK OF FRUIT BARK BEETLE

We have already referred to the similarity between the symptoms of injury made by *E. rugulosus* and that inflicted by *Phloeo tribus liminaris*; likewise, to the gumming caused by the presence of the peach boring moths, *Sanninoidea exitiosa* and *Sesia pictipes*; but, gumming may also be caused by the presence of bacterial diseases. One of these is called gummosis because of the excessive exudations of gum coming from infected pockets on the trunk. This disease is especially apt to accompany a hide-bound condition of the tree, following a severe infestation with San Jose scale. All of these manifestations of injury may be mistakenly attributed to the presence of *E. rugulosus*. The presence of shot-like holes in the bark, and of larvae beneath, and the form and position of the burrows will enable one to correctly separate an attack of the Fruit Bark Beetle from these other maladies.

HOST PLANTS

At Gypsum, Mr. King found the following plants harboring *E. rugulosus:* Cultivated plants; apple, pear, cherry and peach. Uncultivated plants; black cherry (*Prunus serotina*) and wild plum (*Prunus americana*). In addition to this list, Mr. Wilson recorded it at Lakeside on quince and plum among cultivated plants. From the quince a female beetle was taken, and in her burrow 23 eggs were found. European writers had previously recorded most of these hosts, all of the cultivated ones, and in addition thereto the apricot. Mr. F. H. Chittenden adds the nectarine in Cir. 29, Div. of Ent. U. S. D. A. Dobner records mountain ash as an European host, as does Eichoff hawthorn and elm.

PARASITES AND NATURAL ENEMIES

A hymenopterous parasite, *Chiropachys colon*, was quite common about the burrows of *E. rugulosus* in July, 1908. Tiny nematode worms were found by Mr. King as parasites in the bodies of the beetles. In form and color these were like the vinegar eel. *Anguillula aceti*, but smaller, ranging from .28-.44 mm. in length.

The various woodpeckers are voracious feeders upon the larvae, and badly infested trees are sometimes seen in the spring of the year with the bark practically all stripped away from the trunks and larger limbs, and hanging in loosened sheets and shreds over the bare wood—the result of winter work by these useful birds.

In Europe, two hymenopterous parasites, *Blacus fuscipes* and *Pteromalus bimaculatus* are effective agents in keeping the borer in check and deserve introduction into this country. The most common parasite which we already have, *Chiropachys colon*, is sometimes very prolific and effective. Dr. Chittenden notes that in one case, coming under observation at Washington, 92 parasites were reared from infested twigs against 72 beetles that escaped being parasitized. All but two of the parasites were *C. colon*. About one-half dozen other parasites have been reared, from the larvae and a number of predaceous beetles have been recorded as probable enemies.* Up to the present time, none of these natural enemies, except the woodpeckers, have been noted as specially effective in Ohio, though *C. colon* was quite common in 1908, and it may have played a more important part than we discovered in reducing the beetle to comparatively unimportant numbers.

*Circular 29, Div. Ent., U. S. D. A., p. 6.

THE PEACH BARK BEETLE

Phloeotribus liminaris Harris.

HISTORY

This insect was early recognized as a peach pest, Miss H. H. Morris recording the belief in 1849 that it was the cause of peach yellows. The large number of beetles found on trees suffering with this malady constituted the basis of her opinion. Harris in his book on "Insects Injurious to Vegetation," published in 1852, writes as follows: "There is another small bark beetle, the *Tomicus liminaris* of my catalogue, which has been found in great numbers by Miss Morris under the bark of peach trees affected with the disease called "yellows" and, hence, supposed by her to be connected with this malady. I have found it under the bark of a diseased elm, but having nothing more to offer from my own observations concerning its history, except that it completes its transformation in August and September. It is of dark-brown color, the thorax all punctured, and the wing covers are marked with deeply punctured furrows and are beset with short hairs. It does not average one-tenth of an inch in length."

The elm beetle which Mr. Harris supposed to be *Phloeotribus liminaris* has since been proved to have been a different species. Occasional references to the Peach Bark Beetle are scattered through entomological literature between 1852 and 1902, some of these clearly indicating that the serious nature of the pest was recognized by more than one observer. Thus, Prof. C. V. Riley, writing in the Rural New Yorker Dec. 24, 1881, speaks of the "Beetle which is doing such injury to peach trees," further referring to it as an "Old acquaintance long known to injuriously affect peach trees." W. L. Deveraux, in the same issue of the same paper, says: "This beetle is a much more serious pest than any of the other injurious insects attacking and burrowing in the trunk and branches of the peach tree." In the Rural New Yorker of May 19, 1883, W. L. Deveraux writes: "This pest which works so much damage to peach trees," etc. Prof. J. A. Lintner writes as follows in Country Gentleman, July 9, 1885: "The injuries from *P. liminaris* seem to be rapidly increasing. They have been quite destructive for two or three years past at Bethlehem Center in the vicinity of Albany, and what is believed to be the same insect has killed many hundreds of young peach trees at Keuka, Steuben Co., N. Y., the last year." The same entomologist says in the Ninth Report of the State Entomologist of N. Y., in 1892: "If this little beetle once takes possession of a tree, unless it should be found that it can be effectually killed by kerosene as suggested (applied with an atomizer), the fate

of the tree is sealed and it cannot long survive." Prof. M. V. Slingerland in the Rural New Yorker, Oct. 21, 1893, says: "Where the beetles occur in large numbers the tree soon shows the effect of their attack. They are present in alarming numbers in many orchards in N. Y. State and Canada." Dr. James Fletcher in the Twenty-sixth Report of the Entomological Society of Ontario, 1895, speaks of the "Peach Bark Borer (*Phloeotribus liminaris*) which has for some years done so much harm in the peach orchards of the Niagara peninsula." In the transactions of the Royal Society of Canada, Vol. V, Sec. IV, 1899, the same author observes: "One of the most serious enemies of the peach grower in the Niagara peninsula, although frequently overlooked, is this minute Scolytid, which, although one-twelfth of an inch in length, by reason of its attacks and those of its larvae, causes such an enormously disproportionate outflow of gum from the trees that they are soon weakened and killed." In 1909, Mr. H. F. Wilson published as Part IX, of Bulletin No. 68, Bureau of Entomology, U. S. D. A., a comparatively full account of its life history and economy, based upon his observations in the Lake region of northern Ohio. It has been recorded from Michigan and probably ranges farther west than is known. It is at present recorded from New York, Pennsylvania, New Jersey, Ohio, Maryland, Virginia, West Virginia, Michigan, Niagara district of Ontario province, Canada, North Carolina and New Hampshire. Mr. Chas. Dury, of Cincinnati, gives Tyngsboro, Mass., as an additional locality, and has a pair collected by himself at Browsville, Texas, which he "believes to be this species or very close to it." While Entomologist of the Ohio Station, Prof. F. M. Webster, under date of Dec. 31, 1901, makes the following statement in a letter to Mr. Geo. E. Fisher, Freeman, Canada, who had sent specimens of the beetles and samples of their work for identification: "I have only found it, (*Phloeotribus liminaris*), in Arkansas and once or twice in Ohio." Prof. J. M. Swaine says the species continues to be common and injurious in southern Ontario, and is also very common in southern Quebec on wild cherry, but he has never found it in Quebec orchards.

Its most serious injuries have been wrought in Ohio, New York and Ontario. Its devastations have been practically confined to peach, cherry and wild cherry.

OCCURRENCE IN OHIO

The Peach Bark Beetle is a native American insect and before the introduction into this country from Europe of the cultivated varieties of cherries and of peaches, it probably confined its attention to our wild choke and bird cherries, or their near relatives, such as

wild plums. It may have always existed in Ohio and adjoining states, such as West Virginia, where it is known to be widely and quite evenly distributed, but only in recent years has it attracted special attention in our state as a fruit pest. The concentration of peach orchards along the Lake Shore and the unhealthy conditions which have developed in many of these from the work of San Jose scale, other peach pests, and from the neglect of their owners, have produced an environment very favorable to the excessive multiplication of this species. It has been present in injurious numbers over a territory of something like 100 square miles, or most of the Marblehead peninsula and the adjacent islands for the past seven years, and was likely responsible for much of the damage in the same region, which, in the years immediately preceding, was credited to the Fruit Bark Beetle, *Eccoptogaster rugulosus*. Since both insects were generally at work in the same orchards, and frequently upon the same trees, this confusion was very natural and only an expert examination would be likely to discover the presence of both insects. In July, 1907, Mr. W. H. Wright, of Lakeside, called the attention of the writer to his orchard which was suffering greatly from an attack of bark beetles. At the time of the examination, only *Eccoptogaster rugulosus* was noticed, this being the proper time for the culmination of the summer brood of this species, and it was not until Mr. Wilson took up a minute investigation of the insects at work that the presence of *Phloeotribus liminaris* was discovered.

Wherever the orchard owners, generally, have whitewashed or otherwise treated their orchards, and have promptly burned all trimmings and dead wood, there has been considerable abatement of injury. Since these practices became quite general, at least for two or three seasons, the benefits have been quite discernible throughout the whole of the infested district.

Mr. Dury says of its distribution around Cincinnati: "I have never found it very abundant here and I have been collecting in southwestern Ohio for over 40 years." Mr. Wilson, in the publication previously referred to,* speaks of its having been captured at Youngtown, the statement probably being founded on records in the U. S. Bureau of Entomology. A specimen in the collection of the Ohio State University is labeled "Columbus, O., April 20, 1896." We have no knowledge of this species ever having done serious injury in any other locality in Ohio than in the beforementioned Lake district.

*Bulletin No. 68, Part IX, Bureau of Entomology, U. S. D. A.

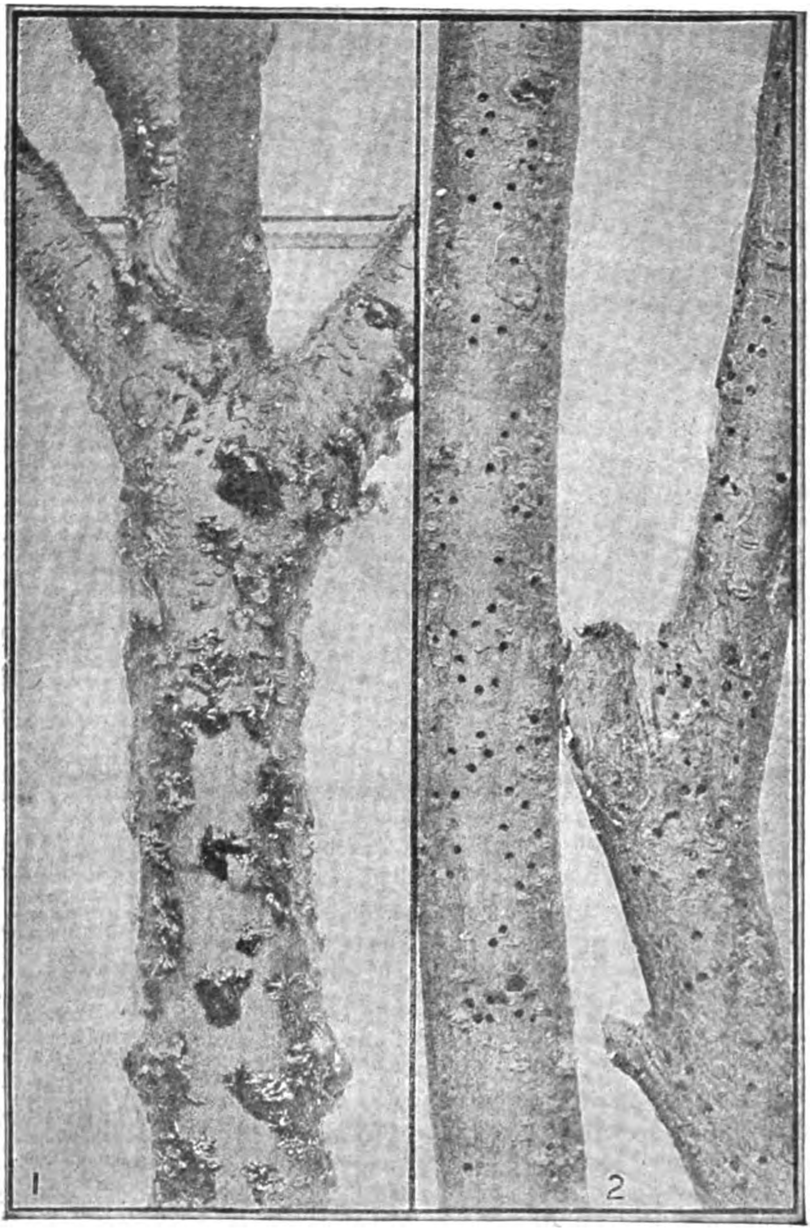

Plate VII. Exit holes and gumming caused by the Peach Bark Beetle, *Phloeotribus liminaris*. Photo. by H. F. Wilson (Bul. Bur. Ent. U. S. D. A. No. 68, Part IX.)

SYMPTOMS OF INJURY

The general symptoms of injury by this species are so like those which accompany the presence of the Fruit Bark Beetle, *Eccoptogaster rugulosus*, that a casual examination of its work is almost certain to lead the observer to attribute the damage to the more common insect. The trees gum copiously, the bark of the trunks and larger limbs being perforated with minute holes resembling the punctures made by fine bird shot, and the inner bark and cambium wood are channeled through in various directions and destroyed. As much as three or four gallons of sap may exude from a single tree of ordinary size in one season. A wild cherry tree, 75 feet or more tall and about 14 inches in diameter, on the Marblehead peninsula, was apparently killed by these beetles alone. If it was assisted by the Fruit Bark Beetle, the work of the latter was undiscoverable. All the bark from this very large tree was completely devoured by the insects. Trees that generally pass without question as healthy are attacked by the beetles for the purpose of feeding, but such trees are not selected for incubation. As winter approaches, the beetles burrow into the bark of healthy trees and construct cells in which to hibernate; a certain amount of gum will exude from each of these holes the next season and, in the spring, when the insects emerge from their winter chambers, they burrow from a quarter to one-half inch in the bark of the same or of nearby healthy trees, and the exudation from these added to that coming from the hibernation burrows, weakens the tree to a considerable extent; and when the attacks are renewed, as is apt to be the case later in the season, and also from year to year, the trees quite soon, almost certainly in three or four years, reach that sickly condition which best fits them to be rearing grounds for the young larvae. Egg burrows and larval tunnels are then made and the larvae quickly complete the destruction commenced by the adults.

DESCRIPTION

Egg: Milky white when first deposited, elliptical in shape, opaque and measuring on the average .44 to .47 mm. or about 1-50 of an inch long and a little more than two-thirds as much through the middle diameter (.36 to .39 mm. as an average,—approximately 1-75 inch). The egg shells are sufficiently tough to easily admit of the removal of the eggs from the burrows without breaking them. They can be more certainly preserved and handled by being boiled for a few moments in water.

LIFE HISTORY AND HABITS

In northern Ohio the hibernating beetles commence cutting their way out from their winter cells with the first warm days of spring, sometimes in late March, but it is generally later than this before the majority of them become active. About the middle of April or a little later, under average conditions, they may be seen issuing in numbers from their burrows and crawling about over the trees. In 1908, activity was observed April 8 in orchards near Lakeside. A beetle, here and there, could be found on the bark, and openings had been quite generally made from the pupal cells to the outside. The beetles would move about somewhat sluggishly when cut out from their burrows, notwithstanding the chilly temperature. April 16, 1912, they were working in peach and cherry at Gypsum, the brownish frass at the mouths of their burrows indicating their whereabouts, and also that they had been feeding for a few days. The interval between their resumption of activity and their appearance outside their burrows, usually of three or four days to a week or longer, is spent in feeding.

Both dead and living wood is used for hibernating cells, and when they leave their winter shelters, they go to either dead or living trees, to wood piles, to brush heaps, or to any wood in which they can feed and rear their young. Migration from tree to tree is usually accomplished in the afternoon, but little flight being indulged in during the morning hours and practically none at night. During the daylight hours, the females seek suitable situations for starting burrows, while the males seek the burrows of females not yet appropriated by males. Flight and movements over the tree cease when nightfall is well settled, though flight seems to be most active just at the twilight hour. Migrational activity apparently commences about the middle of the afternoon.

The burrows of this insect are characteristic and readily distinguishable from those of *Eccoptogaster rugulosus* and other common shot-hole or pin-hole beetles. The entrance to the burrow is partially closed by a gummy exudate, mixed with bits of bark-dust and frass, the mass being bound together with a fine silken thread which is manufactured by both sexes. This mass, partially covering and extending somewhat into the burrow, is not found at the entrance to the burrows of *E. rugulosus*. The female commences burrowing into the bark, nearly always entering at a lenticel, and if the sap in the tree proves scanty, she constructs the brood chamber just between the sapwood and the bark; if, however, the sap is abundant, the galleries are confined to the bark, though sometimes impinging on the sapwood. The main chamber of the burrow may

be anywhere from 1 inch to 2.625 inches long, the average length being about 2.06 inches. The diameter of the main burrow varies between 1-8 inch or less to 3-16 of an inch or thereabouts. It is nearly always formed transversely across the trunk or limb, but is occasionally inclined at an angle of 45 degrees or less to the axis of trunk or branch. Since the main burrows of *E. rugulosus* are more often than not vertical, or nearly so, there need not be much doubt as to which species formed any particular burrow. A fork is formed well toward the inner end of the burrow, commencing at the point where the burrow first touches the sapwood. When the point is struck, the female forms a little niche at an angle to the part already excavated, and she then begins excavating in the opposite direction, thus making another and approximately equal angle with the main burrow. While this opposite extension is being made, the male copulates with the female at the fork. When in copula, the female occupies one arm of the fork, head inward, the point of her abdomen just at the fork, while the male operates from the other arm. At other times, the male may be found almost anywhere in the burrow, between his special niche and the burrow's mouth. Only a single pair are to be found in a burrow. Copulation occurs an indefinite number of times, and has been observed on several

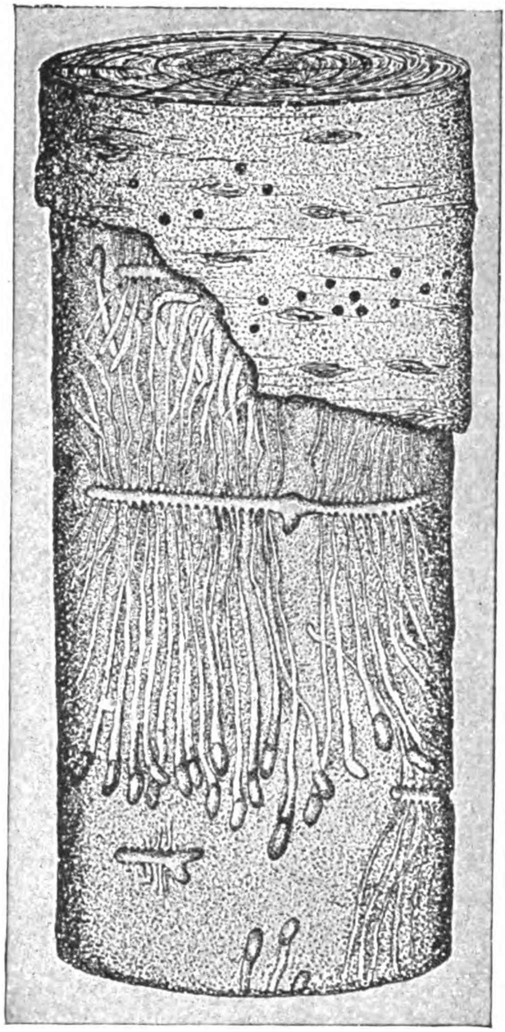

Fig. 7. Brood chamber and galleries of *P. liminaris*.

occasions to continue for 15 minutes and longer after the burrow was cut open. The two forks of the chamber may differ considerably in length. The time consumed in constructing the brood chamber may vary from 10 days to 3 weeks and possibly, under unusual conditions, the period has yet wider limits in both directions. After entering their brood chamber, the male and female of each pair seem to remain there until they die; they may sometimes be found in their burrows, feeble and sluggish, after some of their offspring have reached the beetle stage.

Along the sides of her burrow, the female excavates little niches which may be very close together or considerably separated. These cells are for the reception of eggs, one egg being deposited in each cavity. The eggs are not ranged in straight lines along the sides of the chamber, but may zigzag a good deal. The distance between the eggs is somewhat variable; two may be touching, while others are separated by an interval. However, since the egg-cells are generally located where the bark and the sapwood meet, there will always be two plainly discernible, though not very straight, egg-lines in each burrow. This arrangement holds good in those cases where the burrow is not made next to the sapwood, this sometimes occurring where the bark is very thick; in such a case the burrow is formed in the bark at a depth of about one-fourth inch. As soon as the female has excavated a cell, she backs out of the burrow to the fork, when she reverses her position, and backs into the burrow until she reaches the cell just made, in which she deposits an egg. She then crawls forward to the fork, again turns round and creeps into the brood arm, head foremost. She then proceeds to cover the egg, which stands on end in the cell, with a sawdust-like frass. These sawdust caps over the cells are confluent and form a tubular lining to the burrow, smooth within, and the eggs outside of it. Each egg-cell is filled with an egg as soon as completed, and a new one is excavated as soon as the burrow is extended far enough to make room for it. Deposition of eggs commences as soon as the female has been fertilized, which is generally within a week or so after activity has begun in spring. In 1908, copulation was observed April 24 and eggs were found May 2. In 1912, eggs were found May 5. The length of the egg-laying period is indefinite, seeming to depend on the number of copulations happening to the female, of which there may be several in each case. At the commencement of the egg-laying period the abdomen of the female is much distended. When working without interruption, a female will excavate from 2 to 10 cells per day and deposit an egg in each. A completed brood chamber may contain from 80 to 160 eggs.

In the territory studied, eggs can be found from about the 20th of April until October 1. The fully matured, curved embryo eats its way out through the shell wall at or just above the base of the egg and commences feeding on the under surface of the bark. In dimensions, the new-born larva is slightly longer and a little more slender than the egg. It rests for a short time lying in a slightly curved position in its burrow. The white color of the new larva is soon suffused with pinkish, owing to the bark particles in the digestive tract. Feeding is slow at first and the larvae are several days getting away from the egg-shell, but increase the rate of progress as they grow older. The excrement fills the egg-shells as the larvae gradually work out and away from them, thus permanently marking the location of the shell from which each larva issues. When the bark is removed, the course of the burrow is plainly marked by the line of brownish excrement which completely or partially fills its entire length.

The larvae excavate their galleries at right angles to the parent burrow, generally following the grain of the wood. For some distance out, the galleries lie side by side and parallel to each other, but at a distance of one-half to three-fourths of an inch from the parent burrow, they commence to diverge so that the terminal ends and, therefore, the exit holes form an irregular ellipse around the brood chamber. The length of the larval galleries is from 1.5 to 2.875 inches. The larvae require from 25 to 30 days to become grown, and, when fully matured, they burrow outward making a pupal cell just beneath the outer surface of the bark. They continue development for two or three days in their cells, then, having finished feeding, they void their excrement, becoming clear white instead of pinkish, cast their skins and become pupae.

The pupae are quite active, moving the abdomen continually back and forth. They gradually assume a dark color, and in from 4 to 10 days shed their skins, producing some very tender beetles. These beetles harden up within 4 to 6 days and feed from the walls of the pupal cell. When well hardened, and sometimes before, the beetles cut their way through the bark to the outside, but are not apt to leave the cells until a period of several days to two weeks or longer has elapsed.

NUMBER OF BROODS

There are two complete broods per year in northern Ohio, the summer brood appearing about July 20, reaching a maximum during the latter part of August and gradually dwindling to a few stragglers in late September and early October; and the fall or hibernating brood which yields adults in October and November.

From October until freezing weather, the fall adults are steadily emerging and migrating to growing trees. They enter such trees through rough places on the bark and excavate short burrows from one-fourth to one-half inch or more in length. These burrows are closed in their outer course by the exudation of gum and the beetles utilize the innermost ends as hibernation chambers. The latest formed or retarded adults hibernate in their pupal cells, not cutting their way out until the next spring. Hibernation, therefore, occurs in both living and dead wood, the emerged beetles making cells in the former, and the retarded beetles remaining in their pupal cells in the latter. There is a little overlapping of the summer and fall broods, so it seems there is no time in the year when at least a few beetles cannot be found, if infestation is general and severe. The very late beetles of the summer brood probably do not oviposit in the fall but hibernate with the fall beetles in living wood and reproduce in the spring. The spring brood is at its maximum in numbers and activity in late April and during the first two or three weeks of May, terminating almost wholly by early July, though an occasional specimen will linger until after the appearance of the summer brood in the latter part of the month.

The following table prepared by Mr. Wilson, shows the varying rate of emergence of the summer brood:

TABLE II. Emergence of summer brood of beetles of *Phloeotribus liminaris*

Date[1]	Beetles reared in cages	Beetles from insectary on window screens	Date	Beetles reared in cages	Beetles from insectary on window screens
July 16	2	60	August 25	40	....
" 23	..	30	" 26	60	1,500
" 24	..	74	" 27	86	1,000
" 26	83	....	" 28	69	600
" 27	..	300	" 29	72	1 000
" 28	32	....	September 3	154	200
" 29	30	....	" 4	111	...
" 31	82	450	" 5	40	200
August 4	68	....	" 7	67	75
" 5	..	350	" 10	18	...
" 6	84	500	" 11	38	...
" 6	151	....	" 13	91	40
" 12	268	450	" 15	87	...
" 15	...	1 200	" 17	29	...
" 16	...	750	" 19	12	...
" 17	...	750	" 22	32	...
" 18	317	1 750	" 24	21	...
" 21[2]	327	2 500	" 29	7	...
" 24	129		October 2	4	...

[1] The first column shows beetles actually counted and taken from a breeding cage; the second row of figures shows, somewhat estimated, numbers of beetles gathered on screens at windows. All counts made between 4 and 6 p. m.

[2] This table shows August 21 to be the date of maximum emergence of beetles.

FOOD PLANTS

Mr. Wilson recorded peach, cherry, wild cherry, mountain ash and plum as host plants. He did not find it on plum in the field, but reared it on plum trimmings in a breeding cage, readily getting the

second generation in this manner. Mr. King recorded it from peach, cherry, wild cherry and wild plum growing in the field. Its preference seems to be for peach and cherry, next for wild cherry.

PARASITES

The only parasite found working on this species was a tiny nematode worm, located by Mr. King within the body cavity. The same or a very similar nematode was also found in the body of *E. rugulosus*. Efforts were made by Mr. Wilson to breed some of the parasites of *E. rugulosus* on *Phloeotribus liminaris*, but without success. Where the two beetles were found breeding in the same wood and the parasites of *E. rugulosus* were abundant, there was a corresponding diminution in the numbers of *E. rugulosus*, whereas, *P. liminaris* issued in numbers corresponding to the numbers of larval chambers. Mites, found in considerable numbers in the burrows and clinging to the hairs of the beetles, are apparently not parasites but feeders on the excrement and other decaying matter within the burrows. They attach themselves to the beetles in order to procure easy transportation from one place to another.

REMEDIES FOR BARK BEETLES

So similar are the habits, life-histories and economy of the two species of bark beetles, *E. rugulosus* and *P. liminaris*, that the same measures of prevention and remedy apply to both, and efforts directed especially against one of them will be found to be almost equally effective against the other.

1. **Create an Unfavorable Environment for Propagation:** As indicated in the Introduction to this bulletin, old and neglected orchards that have died from the effects of San Jose scale attack, or which for any reason have become unprofitable and have been allowed to remain standing without care, furnish an ideal incubating ground for these beetles. Large areas on the Marblehead peninsula, adjacent to the villages of Marblehead, Lakeside and Gypsum, planted to peach orchard, are underlaid with valuable lime deposits, and much of this land was purchased a few years since by various syndicates. After these purchases, in some cases, especially where the orchards were infested with San Jose scale, they were totally neglected and allowed to die as fast as they would. These dead and dying trees, with just a little life in them, exactly supplied the conditions most favorable for the multiplication of both species of bark beetles. As a consequence, the insects were soon spread out over all the contiguous peach-growing country, and, when the supply of unhealthy trees was exhausted, they turned their attention to

some of those that were healthy, and by repeatedly attacking them, caused such losses of gum and sap that the trees gradually weakened, whole orchards of good trees being at times threatened with final destruction.

Trimmings and woodpiles constitute a similar source of danger. Many of the orchardists try to conserve the waste products of their farms and wish to utilize the trimmings from their peach trees, also dead trees, for stovewood. Such wood may be profitably burned during the winter months, but, if infested, should not be kept later than the middle of April when the adults of *P. liminaris* become active. If only *E. rugulosus* is present, the woodpile may be continued until the middle of May, but all infested wood, not used up in stoves by the dates specified, should be burned in the open to prevent the escape of any beetles to the orchard: Many cases are known of orchards becoming infested from woodpiles where peach wood was carried over from year to year. We have frequently found several rows of trees, adjacent to the woodpile, suffering greatly, the severity of the attack gradually diminishing as the distance between the woodpile and the trees increased. One of the peach growers in the Marblehead district attributed the commencement of the great outbreak of bark beetles in that territory, about 1906-07, to the use of peach brush as a barrier to protect the shore line near Ohlemacher' Landing against the wash of Lake Erie. The brush was piled in a long windrow along the shore, just south of the terminus of the Toledo, Port Clinton and Lakeside Trolley Line, to prevent the destruction by erosion of a peach orchard adjoining the shore. Several rows of trees in this orchard were killed by bark beetles the following summer, and within two or three years the whole orchard was practically dead. Dead peach wood seems to offer suitable conditions for developing brood as long as the bark adheres to the wood, provided sufficient moisture is present. Messrs. Wilson and Goodwin found piles of dead infested wood in June and July, 1908, well covered with grass of two seasons growth, and, therefore, readily holding considerable moisture. This wood was as full as it could well be of the larvae of both species of bark beetles, thus proving that they breed readily in wood that has been dead and piled on the ground for considerably over a year.

It is obvious that all orchard trees should be regularly trimmed each year, and all dead and sickly limbs, branches and stubs cut away and burned. Very weak trees, as well as dead ones, should be removed and burned. Trees dying late in the summer may be left as traps and cut late in the fall when full of larvae. Trees dying in the spring should either be burned at once or else left as

traps until filled with larvae, when they should be consumed; also, dying trees, of varieties susceptible to infestation, in nearby wood-lots, should be cut down and burned. If whole neighborhoods would cooperate together in these clean culture measures, never through neglect omitting any of them, a general outbreak of these beetles, or even notable damage by them, would be very improbable, in fact, almost impossible.

2. **Cultivation and Fertilization:** Since both of these measures stimulate growth and increase the sap flow, both help the trees to maintain a condition that is unfavorable to production of bark beetle brood, and the wounds made in such trees by the adults to feed are more quickly repaired than is the case with uncultivated and starved trees, when attacked. An abundance of barnyard manure is generally the best fertilizer. However, we have used some combinations of mineral fertilizer on our experimental blocks and have found that they possess some value. On poor land, they would doubtless have proved of much greater help.

3. **Whitewashing and Similar Treatments as Preventives of Attack:** Whitewashing has proved of much value in preventing attack, but under some circumstances its effectiveness is much diminished. We have never known of trees in good general health that did not successfully throw off an attack, if carefully white-washed two or three times per season through a period of two or three years. Old and decrepit orchards can generally be rejuvenated if severely headed back to stubs, cultivated. and fertilized, and then regularly whitewashed for a few years. If there is a nearby exhaustless breeding ground for bark beetles, this treatment may not avail. Thus, we have sometimes had blocks of trees so circum-stanced that they continued to suffer and be reinfested with brood, notwithstanding a heavy coat of whitewash. Whitewash does not interfere in any way with larvae already beneath the bark, but fills up rough places in the bark, thus making it difficult for the females to satisfactorily place their eggs. Also, these beetles, in common with most insects, dislike to expose themselves on a white surface. Whitewash may be made thin enough to apply with a spray pump, but it requires two or three successive applications, a day or so apart, to get a really protective coating. About 4 pounds of table salt to each 50 gallons of spray increases the sticking qualities. Most of our applications consisted of a thick whitewash, with one-fourth pound of salt to each 3 gallons, and these were made with a broom to the trunks and the larger branches. If the beetles are excessively numerous in the neighborhood, make three applications during the season, the first by or before April 1st, the second about the middle of July, and the third by or a little before October 1st.

Of the other washes tried, Carbolineum Avenarius has been the most successful. Used in concentrated form this material is too expensive for use, and is dangerous to the life of even healthy trees. We have seen several trees that were killed outright by being painted with the undiluted material during the dormant winter period. In other cases, trees have survived the same treatment under apparently the same conditions without perceptible harm.

Mr. Wilson found, in some instances, that the larvae in their burrows had been killed where a coating of Carbolineum or of Carbolineum emulsion had been given the bark, while the trees seemed uninjured. Since no observers have since been able to confirm this conclusion, and several have had equally good opportunities to see effects, we believe that results are variable with this mateirial, or else, less probably, that something besides the Carbolineum must have caused the death of the larvae examined by Mr. Wilson. Emulsions of Carbolineum have apparently been somewhat more effective than whitewash for repelling the insects, and in case of severe attack, the extra cost seems to us to be warranted by the results, especially where valuable trees are endangered. The most successful formula we have used for making an emulsion is as follows:

Dissolve 4 pounds of of naptha soap in 4 gallons of water and, while this is boiling hot, remove from the fire and add one gallon of Carbolineum Avenarius, agitating with a force pump, or for small quantities with a rotary egg-beater, exactly as if preparing kerosene emulsion. When well emulsified, add 3 gallons of hot water and apply to the trees while warm. Keep face and hands well protected and horses well blanketed when applying this emulsion, and work only on the windward side of the trees, as it is very penetrating and is likely to cause blistering and sloughing off of the skin, should this become wetted with it. These emulsions of Carbolineum seem not to have injured the trees in any case.

EXPERIMENTAL DATA SUPPORTING CONCLUSIONS AS STATED

The full program of 43 plot tests conducted by Mr. Wilson in 1908 is shown herewith, the number of trees used in each plot being mentioned in connection with each treatment:*

1—Used 16 trees. One part by weight of lime; 2 parts by weight cement; milk used to make a stiff whitewash and applied with a broom to 96 trees, 32 of which were used in experiment No. 2, with the addition of manure. Thirty-two more were used for experiment No. 3, with an application of commercial fertilizer. Sixteen trees of each plat were given a second application, forming experiments Nos. 4, 5 and 6.

*Bull. 68, Pt. IX, Bureau Ent., U. S. D. A.

Date of application, April 9, 1908.

2—Used 32 trees of experiment 1. Barnyard manure spread in a 7-foot circle about each tree, to get value of fertilizers.

Date of application, April 9, 1908.

3—Used 32 trees of experiment 1. Commercial fertilizer applied in a 7-foot circle about each tree.

Cement applied April 9, 1908; fertilizer applied May 7, 1908.

4—Used 16 trees of experiment 1, making a second application.

First application, April 9, 1908; second application, July 3, 1908

5—Used 16 trees of experiment 2, making a second application

First application, April 9, 1908; second application, July 7, 1908.

6—Used 16 trees of experiment 3, making a second application.

First application, cement, April 9, 1908; fertilizer, May 7, 1908; second application, July 3, 1908.

7—Used 2 pounds fish-oil soap per gallon of water (dissolving soap in boiling water) for first application. Used 1 pound of soap to 6 gallons of water for second treatment. Twenty-four trees treated, 16 to be used for experiments 8 and 9.

First application, April 10, 1908; second application, July 7, 1908.

8—To each of 8 of the 24 trees treated in experiment 7 added barnyard manure to find value of fertilizers.

First application, April 10, 1908; second application, July 7, 1908.

9—To remaining 8 trees of experiment 7 added commercial fertilizer, 4 pounds to each tree, spreading in a 7-foot circle.

Fertilizer added May 7, 1908; second application, July 7, 1903.

10—One gallon Carbolineum mixed with 20 pounds of flour, then 25 gallons water added to make emulsion; sprayed 72 trees, 48 of which were used for experiments 11 and 12 to get value of fertilizers.

Sprayed whole tree April 10, 1908; sprayed trunks and limbs below foliage July 6, 1908.

11—Used 24 trees of experiment 10, and added barnyard manure, spreading in about tree in 7-foot circle.

First application, April 10, 1908; second application, July 7, 1908.

12—Used 24 trees of experiment 10, and added 4 pounds of commercial fertilizer to each tree, spreading it in 7-foot circle about tree and harrowing in.

First application, April 10, 1908, second application (3 pounds commercial fertilizer) July 6, 1908.

13—Used 1 gallon Carbolineum, emulsifying it with 4 pounds soap (dissolved in 4 gallons of water) and diluting the whole to 8 gallons; sprayed 144 trees, 96 of these to be used in four more experiments.

Application made April 10, 1908.

14—Used 48 trees of plat 13. Sprayed twice.

First application, April 10, 1908; second application, July 6, 1908.

15—This was to have been a third spraying, but was found unnecessary on account of absence of beetles.

16—Used 24 trees of experiment 13. Barnyard manure (to get value of fertilizers) spread about trees in a 7-foot circle.

First application, April 10, 1908; second application, July 6, 1908.

17—Used 24 trees of experiment 13. Commercial fertilizer added 4 pounds to each tree, spread in a 7-foot circle to get value of fertilizer.

First application, July 3, 1908, (3 pounds fertilizer).

18—Sprayed 6 trees with pure Carbolineum without seeming injury to the trees.

Application made April 9, 1908.

19—Used 25 pounds of lime, 15 pounds sulfur, 6 pounds resin, 3 pounds arsenate of lead, and 50 gallons of water. Applied the mixture with a brush to trunks and large limbs of 6 trees.

Application made April 17, 1908.

20—Same as experiment 19, plus barnyard manure. Two of 6 trees in experiment 19 used.

Application made April 17, 1908.

21—Same as experiment 19, plus commercial fertilizer. Two of 6 trees in experiment 19 used.

Application made April 17, 1908.

22—One gallon Carbolineum, 1 gallon lard and 25 pounds resin. Painted trunks and larger limbs of 5 trees.

Application made April 17, 1908.

33—One bushel tobacco stems boiled for one hour in 4 gallons of water; one-half bushel stone lime and 4 quarts salt added; one-half pint crude carbolic acid used in each 12 quarts of the liquid. All gum and rough bark scraped from the trees and the paint put on with a broom.

Applied the mixture of 72 trees April 22, 1908.

24—Used 24 trees of experiment 23. Same treatment, plus barnyard manure spread in 7-foot circle about each tree.

Application made April 22, 1908.

25—Used 24 trees of experiment 23, plus commercial fertilizer spread in 7-foot circle about each tree.

Applied April 22, 1908; fertilizer applied May 7, 1908.

26—One gallon Chloronaptholeum, emulsified with 4 pounds of soap (dissolved in 4 gallons of water); then added water enough to dilute 25 gallons. Sprayed 120 trees.

First application, April 22, 1908; second application, July 7, 1908.

27—Used 24 trees of experiment 26; added barnyard manure, spreading it in a 7-foot circle about each tree.

First application, April 25, 1908; second application, July 7, 1908.

28—Used 24 trees of experiment 26, adding commercial fertilizer, 4 pounds to each tree, spreading it in a 7-foot circle.

First application, April 22, 1908; fertilizer added May 7, 1908; second application, July 7, 1908 (3 pounds fertilizer added).

29—One gallon Chloronaptholeum mixed with 22 pounds flour to emulsify, added to 30 gallons water, and put on 120 trees with spray pump.

First application, April 17, 1908; second application, July 13, 1908.

30—Used 24 trees of experiment 29; added barnyard manure to get value of fertilizer.

First application, April 17, 1908; second application, July 13, 1908.

31—Used 24 trees of experiment 29, adding commercial fertilizer, 4 pounds to each tree.

First application, April, 17, 1908; fertilizer added May 7, 1908; second application, July 13, 1908.

32—Six pounds arsenate of lead to 50 gallons water; 3 pounds lime added to neutralize the free arsenic. Put on heavy spray; pruned trees before spraying; 170 trees sprayed.

First application, April 20, 1908; second application, July 13, 1908.

33—Boiled lime and sulfur spray (15 pounds lime, 15 pounds sulfur, 50 gallons water.) Excessive application made to 200 trees.

First application, April 24, 1908; second application, July 13, 1908.

34—Self-boiled lime-sulfur wash (15 pounds lime, 10 pounds sulfur, 50 gallons water). Water added slowly so as to prevent burning, stirring vigorously during the process. Sprayed 300 trees.

First application, May 18, 1908; second application, July 13, 1908; to trunks and larger limbs.

35—A stock solution of kerosene emulsion, 20 percent strength, was made and to each gallon of stock solution 2½ gallons rain water were added. Applied with spray pump.

Application made April 20, 1908.

36—Fumigated 6 trees with hydrocyanic-acid gas for one hour, first scraping off all gum and rough bark. Treatment given August 24, 1908.

37—Tree tanglefoot. Put bands around 12 trees and then covered bands with tanglefoot. Application made April 25, 1908.

38—Renovation block. Pruned back severely about 100 trees (girdling 4 trees for traps and not treating them further); applied fertilizer twice and kept trees cultivated all summer.

Plate IX. Photograph in Experimental Orchard; whitewashed blocks and others treated with Carbolineum emulsion. *Photo. by L. L. Scott*

First application, April 19, 1908; fertilizer added May 7, 1908 (4 pounds per tree). Second application, July 3, 1908 (3 pounds fertilizer added).

39—A duplicate of experiment 17 tried on 200 trees; pure whitewash was applied as a second treatment.

Emulsion applied April 21, 1908; whitewash applied September 1, 1908.

40—Placed pieces of branches as traps in trees of small orchard to see if beetles would settle on them.

41—One-half barrel kerosene emulsion used instead of water to make a good, stiff whitewash, applying with broom to plat of 200 or 300 trees.

First application made May 4, 1908; second application, July 9, 1908.

42—One gallon of Chloronaptholeum added to every barrel of whitewash used. Whitewash made as thick as possible and applied with a broom to plat of about 200 trees.

First application, May 6, 1908; second application, July 9, 1908.

43—One gallon of Avenarius Carbolineum added to each barrel of whitewash used; whitewash made as thick as possible and applied with a broom to a plat of about 200 trees.

All fertilizer used in above experiments was of the following formula:

Phosphoric acid	8	percent
Nitrogen	5	"
Potash	2	"

All trees fertilized made a growth of rich green foliage and the trees looked healthy, yet many of them were again attacked by the beetles.

Mr. Wilson summed up the results of this set of experiments as follows:

"The first 6 experiments seem to show that whitewash acts as a repellent, not affecting the beetles once they are in the bark, but if the trees are kept well coated the beetles do not seem to attack the whitewashed parts. The addition of fertilizer to the trees causes a strong flow of sap which, exuding through the burrows, seems to repel the beetles. The treatments given in Nos. 7, 8 and 9 seemed to have no effect whatever. In experiments 10, 11 and 12 the beetles in the tree at the time of application appeared to be killed, but the mixture did not act as a repellent and beetles settled on the trees again in a short while. Experiments 13, 14, 15, 16 and 17 were more promising, and two applications a season would undoubtedly keep the beetles down. The expense of these

experiments, however, makes them impracticable as tried here. In experiment No. 18 all beetles attacking the trees at the time of application were killed, and others did not settle on the trees during the entire season.

The cost of materials used in this experiment, however, makes the treatment impracticable. Experiments 19, 20 and 21 had no effect whatever, neither killing the beetles in the trees nor repelling others. In experiment 22, all trees treated were killed. Experiments 23, 24 and 25 gave very good results, the whitewash sticking well and the beetles not attacking the trees until long after the whitewash had fallen off. Experiments 26, 27 and 28 seemed to have had very little effect on the beetles in the bark and did not repel later attacks. Experiments 29, 30 and 31 failed to give any beneficial results, the emulsion being very poor, as the oil became partly separated from the mixture before the latter could be applied. Experiments 32, 33, 34, 35, 36 and 37 gave only negative results, neither killing the beetles in the burrows nor repelling later attacks. In experiment 38 a plat of 100 trees was used. Fifty of the trees were very severely cut back and 4 or 5 of them, being too weak to recover, died. The other 50 trees were sprayed with lime-sulfur wash. At the end of the season the pruned trees had produced a strong, healthy foliage and the beetles were attacking them but little. The untrimmed trees were badly attacked and had thrown out a scant, sickly-looking foliage. Experiment 39 gave satisfactory results. All of the beetles in the trees at the time of application were killed and no more settled on them until about the last of September; then a few having settled, the trees were whitewashed and further injury was stopped. The cost of this treatment, as made here, prevents it being practicable for a large orchard unless the amount of material used can be reduced with equally good results for the weaker emulsion. Experiment 40 showed that the beetles attack the trees in which these cut branches were placed without settling on the cut branches. Experiments 41, 42 and 43 showed the most practicable, and at this time the most likely remedies. These are the combinations of a whitewash and an oil, the whitewash probably being the main factor in repelling the beetles. The cost of these experiments was 1¼ cent per tree for each application. The trees in these plats, while not entirely free from further attack during the season, suffered considerably less than surrounding plats of trees."

The following year Mr. L. L. Scott made applications on a much larger scale of those remedies which Mr. Wilson had found most promising. The general plan of experimentation in 1909 was as follows:

LARGE SCALE EXPERIMENT

1—Cut back a badly infested block of trees to stubs of main limbs, fertilize and whitewash.

2—Fertilize and whitewash a slightly infested block.

SPECIAL TREATMENTS FOR BADLY INFESTED BLOCKS

3—Cut back to stubs.

4—Cut back to stubs and fertilize.

5—Fertilize, with ordinary sort of trimming.

6—Same as 4 with whitewash added.

7—Trim in ordinary way and whitewash.

8—Cut back and whitewash.

9—Spray with 12 percent Carbolineum emulsion, and trim in ordinary way.

10—Same as 9, but cut back to stubs.

11—Same as 9, but cut back and fertilize.

12—Check.

Each block used in these experiments approximated one-half acre or more of trees. Mr. Scott summed up the results of his season's work as follows:*

"A large number of remedies were tried during the season of 1908 and during the past season only those were tried which gave best results the previous year. Among these, several seemed to give about equally good results; but one appeared to do a little better than the rest, and it may be well to present that here.

Two blocks of Elberta trees were selected and on one an application of a seven percent soap emulsion of Carbolineum Avenarius was made, and on the other a twelve percent emulsion was applied, and since both of these blocks grew so well, had such thrifty green foliage and seemed so free from beetle attack, it appeared that these emulsions were about the best remedies tried.

Carbolineum is a wood preservative and is corrosive to the flesh, so naturally can not be applied when trees are in foliage else the leaves will all be burned, so that the applications necessarily have to be made when the trees are still dormant, or at least before the leaves open in the spring, and then the spray should only be directed against the trunk and bases of the larger limbs of the tree, or there may be danger in injuring some of the unopened buds. A Bordeaux nozzle may be used, and was quite satisfactory if held with the spread of the spray parallel to the trunk and limbs. As a further remedy, it is well to follow the practice of many and whitewash the trees a little later in the spring, and again in the late summer, if there is

*Forty-third Annual Report, Ohio State Horticultural Society, January, 1910.

time; the whitewash not only acts as a preventive against the beetle but it also serves to keep the bark of the tree smooth, and in addition it gives the orchard a nice, clean appearance, which is a point worth considering by any grower.

If trees are so badly infested by the beetle that they cannot be saved in any way, they should be dug out during the winter and burned immediately, as in this way thousands of hibernating larvae will be destroyed, which would cause a more serious infestation the following year if the brush were allowed to lie around unburned.

Where trees are quite badly infested, but there is a possibility of saving them, cut out all infested parts and severely head back the entire tree; then fertilize well with some good, complete commercial brand, and give the tree thorough cultivation in order to stimulate as healthy a growth as possible, so the tree may recover from the attack.

Finally, with healthy trees to begin with, give them all the care and attention they demand, feed them, care for them as you would expect to for any other living thing on the place, and it is altogether probable that an attack will be postponed if not entirely averted."

In 1907, a vigorous young peach orchard of about 100 trees at Longley, Ohio, was severely attacked by *S. rugulosus*. An old apple orchard nearby had been killed by scale and the trees had been gradually cut down and the wood kept for stovewood. The beetles started with these conditions and bred rapidly. The peach orchard had never been very scaly and was sprayed regularly with lime-sulfur wash. Notwithstanding the general good health of the trees a few had died from repeated attacks by the beetles and many were gumming badly. By advice of the writer, the owner of the orchard painted the trunks and larger limbs with a stiff paint made by mixing together Portland cement and water. By the spring of 1908, the condition of the trees was greatly improved.

April 10, 1908, one-half of the orchard was painted with water-cement, and of the remaining half, one tree was painted with pure Carbolineum, 5 others were painted with almost pure Carbolineum which separated from and floated on the top of an imperfect emulsion, while the remainder were sprayed by means of a hand pump with a 12½ percent good and stable emulsion of Carbolineum.

These treatments were repeated July 11, 1908, by Mr. H. T. Osborn. At this date, the tree which had been painted with pure Carbolineum was practically dead, and the other 5 that received treatment with Carbolineum very little diluted, were in an unhealthy, bark-bound condition. All other trees were in excellent condition, and the beetles had apparently abandoned the orchard altogether, quitting the checks as well as the treated trees.

In July, 1910, Mr. Whitmarsh whitewashed a block of trees in the Duroy and Yule orchard which were being attacked by bark beetles, using a spraying machine to make the application. October 26, 1910, he entered the following note: "Today I visited the orchards of Mr. Yule and found the orchard which I had sprayed thoroughly in July, with whitewash, to be badly infested with beetles on the two north rows and not quite so badly infested on the third row from the north side; south of this I could find but few beetles. The probable cause of this infestation was due to the stumps of old trees north of the above orchard and only separated from it by a narrow driveway which is literally swarming with beetles, both *P. liminaris* and *E. rugulosus*. This infestation could probably have been avoided partially or altogether, by thoroughly whitewashing in early September before the hibernating brood of *P. liminaris* emerged. They had bored into the bark very extensively by October for hibernating or feeding, an earlier date by two weeks than such wholesale burrowing is usually done."

The history of a number of orchards in the infested neighborhood confirm the results obtained in our experiments, or in some cases the statement can be reversed, and it should be said that our experiments confirmed the results obtained by the orchardists.

In Mr. Scott's notes for 1909, I find the following entries:

July 1. "One block of trees (back of Mrs. S. L. Kinglets) which was badly infested last year, but received treatment, shows scarcely any beetles at all."

July 30. "In looking over the experimental orchard, I find that some of the weaker trees show some beetles attacking them, noticeably on those parts of the tree which are partly dead or dying. On other more healthy parts of the same trees the beetles have made attacks but in most instances are repulsed by the copious exudations of sap. Such attacks usually extend well into the top and smaller limbs of the trees and in several instances the loss of sap has been great enough to so weaken the trees that egg burrows can be completed without the beetles being driven out by the flow of sap.

One tree, on the row receiving only whitewash, is quite badly infested and will die, notwithstanding the treatment given. This tree is situated in a low and wet spot which contributes to lower the vitality of the tree so the beetles can obtain a foothold. Several of the weaker trees which received 12 percent Carbolineum emulsion show attack more or less serious, as do also weak trees treated with Chloro-naptholeum emulsion and with whitewash cement."

"Out of the block treated with 12 percent Carbolineum emulsion, 3 trees died and 2 others were weakened, but are now recovering.

The other trees in this block were not injured at all. On the contrary, the foliage seems to be a darker green and more healthy and luxuriant than it is on some of the other trees, and the fruit is abundant and maturing in good form. Trunks and limbs are smooth and healthy, but are coated a dark brown. This results from a well-mixed emulsion, applied while warm. The emulsion killed the small twigs (more or less tender) on the trunks and near the bases of the larger limbs. Older and more mature wood was not injured. The 3 trees killed by application of the 12 percent Carbolineum emulsion were cut down today and placed in the out-door insectary for beetles to emerge. The main limbs and many of the smaller ones, even to the top of the tree, were full of larvae in all stages, from those just hatched to full grown ones, and some pupae were found. Cutting into some of the burrows, both *E. rugulosus* and *P. liminaris* were found, the former probably being most numerous. The block of trees on the Wolcott place, treated March 1, by Mr. W. H. Wright, with pure Carbolineum are all dead. The trees have the appearance of having been varnished. Cutting into the bark, the liquid seems to have penetrated to the living cells and killed the protoplasm."

In March, 1908, the author was called to visit the orchard of Mrs. T. S. Johnson, near Gypsum, Ohio. A block of this orchard adjacent to the woodpile was suffering severely from an attack of bark beetles, the insects evidently issuing from the wood, which was peach, of one or two year's harvesting. In 1908, the diseased trees were cut back and treated with whitewash or Carbolineum emulsion. The following year, 1909, Mr. L. L. Scott entered the following observations, July 26th:

"In looking over this orchard I find that as a general thing the treated blocks are comparatively free from attack of bark beetles. The stubs cut back and sprayed last fall and spring with 12 percent Carbolineum emulsion are all dead, only one or two showing any green shoots and these are dying. Blocks not cut back but sprayed this spring with 12 percent Carbolineum emulsion seem healthy; they have a dark green foliage and very few beetles can be found on them, except on some limbs partly dead and, even here, they are not numerous. A few places were found where beetles had started to bore into healthy limbs, but they had only eaten through the cortex and then quit. No sap had exuded, so it seems probable that the beetles were repulsed by the odor or by the taste of the Carbolineum in the bark. Blocks of trees cut back and whitewashed are sending out a vigorous growth of new shoots and all seem to be living. No beetles could be found on the whitewashed trees, except where a

limb was dying and was so far gone that it had failed to send out any new growth. Remainder of orchard, which was whitewashed without cutting back, is thrifty and few beetles can be found, except on weak, dying limbs. In general, the treatment seems to have been quite effective."

June 2, 1910, Mr. Whitmarsh entered notes as follows: "Visited Mrs. T. S. Johnson's estate and found the adult beetles of *P. liminaris* working to some extent in a few trees, but was unable to find any of *E. rugulosus*." Oct. 24, 1910, he made observations as follows: "Visited Mrs. T. S. Johnson's and went through the peach orchards with Mr. Adams, who is in charge of them. The beetles were working to some extent, but, on the whole, did not seem to be doing so much damage as they did in the spring and summer. The trees treated with whitewash, and those treated with Carbolineum, and those not treated at all seem to show very little difference as regards bark beetle work. Of the small number of trees treated with the Carbolineum, as noted above, several had died, but I hardly think that it was due to the Carbolineum as the trees were very weak when treated, and probably would have died regardless of any or no treatment. The healthy trees show no ill effects of the spray."

Mr. Whitmarsh made the following record for the Dailey orchards: "July 7, 1911, I visited the large peach orchards of F. W. Dailey & Son, and found that they had the beetle under control. They have accomplished this by thoroughly applying the following mixture three times per year for the past five or six years: One bushel lime, 40 gallons water, 2 gallons Rex lime-sulfur solution, and a couple of handfuls of salt. Mr. Robert Dailey, with whom I talked, said that the orchard was badly infested five years ago, but at the present time a beetle can hardly be found. He expects this year to make only two applications of whitewash, deeming the third unnecessary with the beetles so nearly exterminated."

Mr. Geo. Mallory reported good results from the use of one pint of pine tar to one barrel of whitewash.

Mr. J. L. King made a trip, May 1, 1912, over the ground on which Mr. Wilson and Mr. Scott worked and reports as follows:

"The orchards of Duroy and Yule were thoroughly examined and only two beetles could be found in an old Salway orchard. From Duroy's to Jacobson's many neglected orchards were observed, but only a very few beetles (*P. liminaris*) found. On a wild cherry at Mrs. Jacobson's, quite a few burrows were located in the deep furrows of the bark. Farther east a few more beetles were found in cherry, but in all cases the numbers were small. The orchards of the Kelley Island Lime Co. were all dead, showing the carvings of

P. liminaris in great numbers. They were too old to sustain beetles or larvae any longer. Many of these had been cleared away and burned. Mrs. Jacobson's orchard, which was whitewashed, pruned and fertilized, was doing nicely and had made a vigorous growth in 1911. Mrs. Jacobson states that this orchard was badly infested with bark beetles in 1908, so much so that it was turned over to Mr. Wilson for experimental use. He whitewashed it, pruned it severely, and fertilized it. This strengthened it to such an extent that the bark beetles were entirely resisted."

The beetles appeared in some numbers in the orchards of Mr. S. R. Gill and also those of Mr. Wm. Miller, but soon disappeared. Proper care, cultivation, fertilization, trimming and spraying, with a judicious use of fire, probably operated strongly against the beetles in these orchards, but these routine measures were supplemented to some extent for at least one or two seasons with some whitewashing, a small quantity of Carbolineum being sometimes added to the whitewash.

These experiments and observations confirm the efficacy of the earlier remedies recommended for these insects. Thus, in the Rural New Yorker, May 19, 1883, W. L. Deveraux writes concerning *P. liminaris*: "By simply deferring pruning until early July we may be sure of finding the whole family at home, including the entire progeny for the next year, or the trimming off of all dead limbs may be done in winter or spring and the brush may be piled up in the orchard and await the planting of the brood chambers before applying the torch. They choose trees having rough bark; but they can enter the smoothest twig or young growth as I have observed them do in experimental tests. Thus, if they are headed off by the presence of tar-lime or soap on the trunks, they will repair to the branches and forks."

Dr. James Fletcher in the 26th Rept. Ent. Soc., Ontario, 1895, makes the following observations: "The Peach Bark Borer (*Phloeotribus liminaris*) which for some years has done so much harm in the peach orchards of the Niagara peninsula, has this year been successfully treated by Mr. C. E. Fisher of Queenstown. Noticing that the perfect beetles became active very early in the spring, he would wash his trees with a strong alkaline wash to which carbolic acid had been added. He made his wash as follows: Five pounds of washing soda, three quarts of soft soap and enough water to make six gallons. Air-slaked lime was then added sufficient to make it of the consistency of thick paint. To all this was added three tablespoonfuls of Paris green and one ounce of carbolic acid. This mixture was applied with a whitewash brush, thoroughly

covering the entire trunk of the tree and a few inches up on the limbs. Mr. Fisher reports that at the end of the season he is quite satisfied with the results of the treatment. It would appear from what I have just said, that two applications of this mixture, the first one being made as soon as the beetle becomes active, sometimes as early as March, and another six weeks later, would provide us with an effective remedy for this little pest which for some years has done considerable harm in our Canadian peach orchards."

PIN HOLE BORERS

There are a considerable number of Scolytid beetles, other than the two species which we have treated at length, that work in the heartwood of trees as well as in the sapwood, most of them having a long list of hosts besides orchard trees. The external openings of their burrows resemble those of the bark beetles previously described, but on the average are smaller and suggest pin holes rather than shot holes. These beetles which penetrate the heartwood are less to be feared than those which have the habit of concentrating in great numbers in the growing bark. However, they are sometimes both numerous in and damaging to fruit and other trees. They may cause discoloration of the wood through which their burrows pass, the "blued" or stained areas exhibited by various timbers, when split, often being caused by them. Again, they may fill what would otherwise be valuable timber, so full of pin holes that it is worthless. Some of the species, instead of living upon wood or bark, derive their sustenance from a fungus which grows along the walls of their burrows, and which they introduce and propagate as carefully as the farmer does his grain. Whether or not the burrows are designedly utilized for fungus pastures, they furnish, especially after being vacated by the beetles, entrance for accidental germs of all sorts of ferments, rots and decay.

It seems that, in some cases, where the food supply is abundant and other conditions are congenial, the beetles, upon reaching maturity, do not go outside their burrows to seek new trees, but start new burrows off the old ones, and thus the work of destruction goes on with an acceleration exactly proportioned to the geometrical rate of increase of the insects. However, the fact that the fungus-feeding species are dependent on the normal development of their fungus pastures naturally limits their multiplication, and at the same time suggests effective remedial measures. The young larvae browse on the tender, newly-formed parts of the fungus, while the adults clip back the older and tougher threads. If, for any reason,

the pasturage is interrupted by a reduction in the number of beetles, or if conditions favor a specially exuberant growth of the fungus, there is great likelihood, according to Mr. H. G. Hubbard, that it will over-run and choke the burrows, at the same time overwhelming and suffocating the occupants. So perilous are the conditions under which these insects must propagate, that it is surmised that only under exceptional circumstances does it happen that more than one generation is produced in the same burrow. This is probably the reason why these little pests have never attracted much attention or become wholesale pests in an orchard. If the burrows are closed, the fungus may either fail, or it may over-master the panic-stricken beetles which cannot escape. Therefore, whitewashing or coating the trunks with thick, soapy preparations, or spraying oil emulsions into the burrows to kill the fungi, may all prove very effective measures. Driving wooden pegs or short wire plugs into the external openings of the burrows or pinholes will accomplish the same end. Or, perhaps, poles stuck in the ground will serve as traps and attract the beetles away from the living trees. Bisulfide of carbon may be injected into the holes and the openings then closed with a plaster of mud, putty or grafting wax. In case of severe attack, the trunks and larger branches might be protected by being wrapped with newspapers or old cloths, but for large scale treatment the orchardist will obviously have to depend largely upon keeping his trees in a healthy condition, as free as possible from mechanical injuries and abrasions, and such an operation as whitewashing.

Weakened and unhealthy trees are the ones apt to be attacked, just as is true in the case of the true bark beetles; so proper orchard hygiene, sufficient cultivation, good and abundant fertilization, and correct spraying will furnish the surest safeguards against attack. Where a very few trees are involved, it may be advisable to cut them down at once and burn, if the attack is serious. In case of specially threatening conditions for a whole orchard or neighborhood, should such ever develop, it would be advisable to add whitewashing or similar treatment to the best orchard hygiene; and, further, it might be worth while to girdle a few forest trees, if these were known to be preferred food plants, so as to weaken them and attract to them all the beetles in the neighborhood; after which, while inhabited by the insects, they could be cut down at the most advantageous date and burned.

Brief accounts of some of these pinhole borers affecting orchard trees follow:

BANDED PIN-HOLE BORER

Monarthrum fasciatum Say.

This little beetle is more of a timber pest than an orchard enemy, but a number of times it has been recorded as injuring apple and peach. Mr. G. C. Davis, in 1895 (Trans. Mich. Hort. Soc.) reported this species and the following one injuring peach, both having been previously recorded on apple. Prof. F. M. Webster also recorded it on peach in August, 1895 from Noble County, O. (Ohio Farmer, Aug. 22, 1895). Mr. R. D. Whitmarsh of this Station, under date of June 2d, 1910, speaking of a visit to the orchard of Mrs. T. S. Johnson, Port Clinton, O., says: "I found two peach trees in the orchard just south of the house very badly infested with beetles and, on examination, I found that the borer causing the destruction of the tree was neither *E. rugulosus* nor *P. liminaris*, but *Monarthrum fasciatum*. Mr. J. L. King, May 8, 1912, reports finding this species working on peach in the same orchard. He says: "The beetle was working in the green wood 5 feet above the ground. The burrow was started through a lenticel opening. A second specimen was taken May 20 in much the same environment as the first." Mr. King also enters the following note: "Oct. 14, 1912: In the branches of a dying cherry tree at Mr. Wright's (Lakeside, O.) I found a number of specimens of *M. fasciatum*. The beetles were in long burrows in the heartwood. I find that there is a slight tendency for these beetles to follow the annual rings in the formation of their burrows. As many as three and four beetles may be found in a single burrow. The work of this species is easily distinguished from that of *P. liminaris* and of *E. rugulosus* by the entrance hole and by the white wood-frass which is found at the mouth of the burrow. No eggs nor brood was found in any of the burrows opened." Mr. E. A. Schwartz noted in 1886 that "The main gallery runs in the solid wood concentric with the bark; while the secondary galleries branch off rectangularly from the main gallery and run upward or downward."* He also reported finding about 20 specimensof the beetle in a single gallery. Mr. H. G. Hubbard states that the egg-laying and feeding habits of this species are exactly the same as those of the next species treated. Besides feeding in apple, peach and cherry, Hopkins† lists it, from various authorities, infesting pine, white oak, black oak, basswood, beech and hemlock. He also gives the following dates for capture of adults: Feb. 20, March 2, April 14, 15, 17, 18, May 18, July 21,

Fig. 8. *Monarthrum fasciatum*, enlarged. After Hubbard, Bur. Ent., U. S. D. A., Bul. 7, New Series.

*Proc. Ento. Soc. of Wash. Vol. 1, P. 44.
†Bulletin 32, W. Va. Agr. Exp. Sta.

Aug. 6, 22, Sept. 3. Mr. Chas. Dury reports it as abundant at Cincinnati and gives the following dates of capture: May 7, July 13, Sept. 8, etc. An examination of these dates and our own records indicates the possibility of an early and a late brood, with great irregularity of development, or a single irregular generation may be the rule. Besides the Ohio localities given, there are some specimens in the Ohio State University collection, labelled Columbus, O., and others Defiance, O. In our collection is a number of specimens sent in by D. W. Morrow, Glenville, O., June 1, 1900, taken from maple; they were eating into the bark and wood.

Fig. 9. Gallery of *M. fasciatum*, much reduced in maple. After Hubbard. Bul. No. 7, New Series, Bur. Ent. U. S. D. A.

This has never been a serious orchard pest nor is it ever likely to become such; however, according to our observations and those of others, it may occasionally destroy one or more trees, usually weakened ones.

The beetle is slender and cylindrical in shape and about .10 inch or 2.4mm. long. The antennae are clubbed and in the male are fringed with very long hairs, while in the female, the hairs are few and short, and located on margin of club. The posterior declivity of the wing covers is hairy; and the front part of the wing covers is occupied by a yellow band, the posterior third being black. According to Leconte, it ranges from Lake Superior to Florida.

APPLE PIN-HOLE BORER, OR APPLE STAINER

Monarthrum mali Fitch.

This species is quite similar in habits and general appearance to the preceding species, but is somewhat smaller (2mm. or .08 inch long) and the male is provided with a long, terminal spine and a few hairs at end of club; spine is wanting on club of female. Fitch,* in his original treatment and description of the species, says: "Young thrifty trees, soon after putting forth their leaves in spring, suddenly withering, as though scorched by fire, the bark becoming loosened from the wood, and soon after numerous perforations like pin-holes appearing, penetrating through the bark into the wood, from each of which comes out a very small cylindrical beetle which is smooth, slender, black, sometimes dark chestnut red," etc.

He further states: "I only know this insect from specimens recently sent me from Middlefield, Mass., by Lawrence Smith, Esq., who writes me that he took them July 6, from the trunk of an apple

*Third Report on Insects of N. Y., 1856.

tree ten inches in diameter, which was numerously punctured from the surface of the ground to where the limbs commenced branching off, above which no traces of them were to be found. In another letter, he states that this insect was first noticed in his neighborhood two years ago, when several nursery trees were riddled by them. Nothing was seen of them last year; but they have reappeared the spring of the present year (1857) in greater abundance, and a number of trees have been ruined by them. I find a specimen of this same insect also in a collection sent me several years since from Ohio, by Dr. Robert H. Mack, of Parma." G. C. Davis recorded it on peach in Michigan (Trans. Hort. Soc.) in 1895. Hopkins* gives the following list of host plants; pine, white oak, black oak, jack oak, elm, beech, maple, chestnut, basswood, honey locust, yellow poplar (tulip), buckeye, Morello cherry, cedar and hemlock.

Fig. 10. *Monarthrum mali*, enlarged. After Hubbard, Bul. No. 7, N. S. Bur. Ent., U. S. D. A.

Mr. King took a specimen in Mrs. T. S. Johnson's orchard, Port Clinton, May 25, 1912, and in the State University collection are specimens taken at Columbus, O. Mr. Dury has taken it at Cincinnati, but says it is not common there.

The following is a resume of its feeding and breeding habits, extracted from the writings of H. G. Hubbard:† "The young are raised in separate pits or cradles, which they never leave until they reach the adult stage. The galleries, constructed by the female beetles, extend rather deeply into the wood, with their branches mostly in a horizontal plane. The mother beetle deposits her eggs singly in circular pits which she excavates in the gallery in two opposite series, parallel with the grain of the wood. The eggs are loosely packed in the pits with chips and material taken from the fungus bed, which she has previously prepared in the vicinity, and on which the ambrosia has begun to grow. The young larvae, as soon as they hatch, eat the fungus from the chips, and eject the refuse from their cradles. At first they lie curled up in the pit made by the mother, but as they grow larger they deepen their cradles with their own jaws, until, at full growth, they slightly exceed the length of the larva when fully extended. The larvae swallow the wood which they excavate, but do not digest it. It

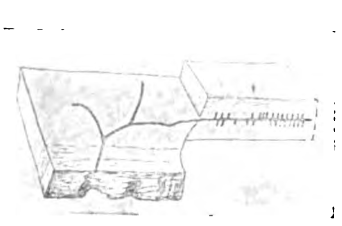

Fig. 11. Gallery of *M. mali*, much reduced. After Hubbard. Bul. No. 7, N. S. Bur. Ent., U. S. D. A.

*Bul. 31, W. Va., Agr. Exp. Sta.
†Bul. No. 7, N. S., Bur. Ent. U. S. D. A., P. 9.

passes through the intestines unchanged in cellular texture, but cemented into pellets by the excrement, and is stained a yellowish color. The pellets of excrement are not allowed to accumulate in their cradles, but are frequently ejected by them, and are removed and cast out of the mouth of the boring by the mother beetle. A portion of the excrement is evidently utilized to form the fungus garden bed. The mother beetle is constantly in attendance upon her young during the period of their development, and guards them with jealous care.

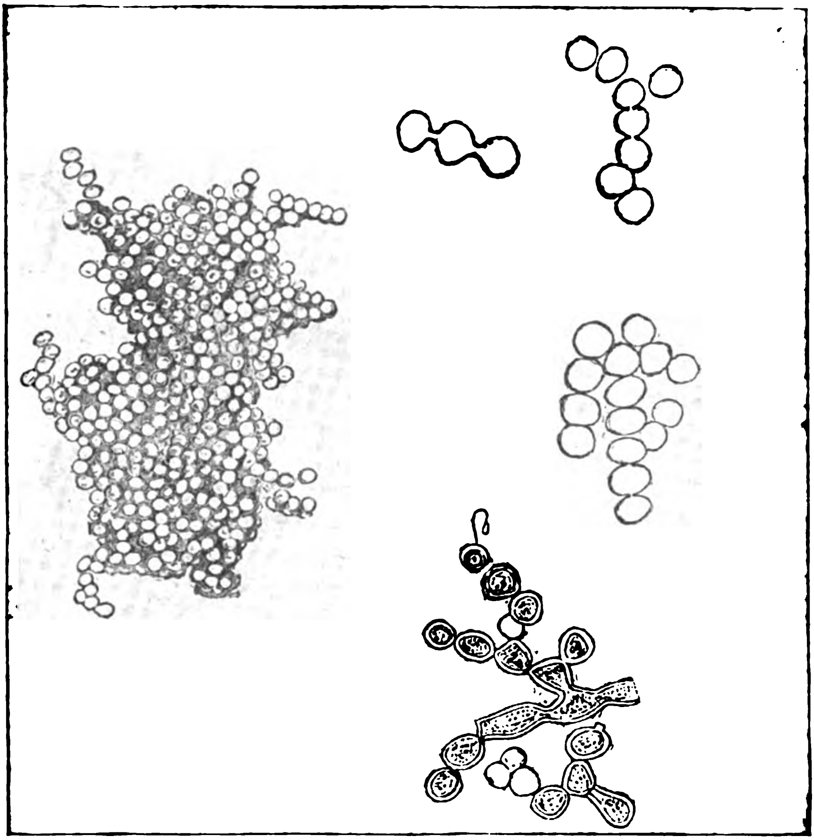

Fig. 12. Ambrosia of *M. mali*, greatly enlarged. After Hubbard. Bul. No. 7, N. S. Bur. Ent., U. S. D. A.

The mouth of each cradle is closed with a plug of the food fungus, and as fast as this is consumed it is renewed with fresh material. The larvae from time to time perforate this plug and clean out their cells, pushing out the pellets of excrement through the opening. The debris is promptly removed by the mother, and

the opening again sealed by ambrosia. The young transform to perfect beetles before leaving their cradles and merging into the galleries.

The Ambrosia of *Monathrum* is moniliform and resembles a mass of pearly beads. In its incipient stages, a formative stem is seen which has short joints that become globular conidia and break apart. Short chains of cells, sometimes showing branches, may often be separated from the mass. The base of the fungus mass is stained with a tinge of green, butthe stain in the wood is almost black.

Two species, *M. fasciatum* Say and *M. mali* Fitch are confined to the Atlantic forests, and range in latitude from Lake Superior to Florida. They have identical habits, and feed upon the same fungus. They are commonly associated in the same tree-trunk, not seldom occupying galleries having a common entrance hole. Both species are known to attack wine casks, but they probably breed only in dying trees.

Perhaps the most effective method of preventing injury to wine, cider and vinegar casks is to keep them in dark cellars or darkened rooms as the insects seem to shun such situations. Painting the casks with white paint, with Bordeaux mixture, with whitewash, or with Carbolineum would doubtless assist in repelling the beetles. They probably resort to casks only for the purpose of feeding, as no record has been made of their breeding in such situations. Staves, or wood intended for making barrels or other articles, if infested with these or other timber beetles in whatever stages of development, can be freed from living forms by subjecting the wood to live steam or dry heat for a few hours.

It is improbable that any of these insects would survive 150° Fahr. if continued for 2 or 3 hours.

The trees attacked include oak, hickory beech, maple, aspen, apple and orange, and the list might be extended to include other hardwood timber.

Hopkins gives the following dates for capture of adult beetles: Feb. 20, March 14 to 19, May 4, 8, 30, July 16, 20, 21, 24, 25, 29, 30, Aug. 4, 12, 22, Sept, 3, Dec. 6, Jan. 31. Pupae, eggs and larvae were found July 21. There may be one, two or more broods per year so far as can be inferred from these dates. The beetle ranges from Lake Superior to Florida according to Le Conte.

PEAR BLIGHT BEETLES

Xyleborus dispar Fabricius and *Xyleborus pyri* Peck.

Two other scolytids which may occur in Ohio but which, so far as we have been able to learn, have never been definitely recorded in the state, are *Xyleborus pyri* and *Xyleborus dispar*. The latter

species is an importation from Europe, pitchy brown to black in color, the wing covers inclining to reddish brown. The female is about one-eighth of an inch long, the male considerably smaller. It is known as the Pear Blight Beetle and is injurious to pear, apple, plum, cherry and several kinds of forest trees such as hemlock, beech and oak. It partially girdles young trees, sometimes before they leave the nursery, this causing the death of the upper parts. It tunnels into the trunks of older trees and hollows out the pith and centers of small twigs. The openings into the burrows are small and circular, as is usual with the shot-hole borers. The life cycle in America has not been very thoroughly worked out, but the data gathered indicate the probability of finding the adult beetles packed in the tunnels, end to end, forming a continuous line in the fall and winter months. The eggs for the autumn generation are probably laid in August and September, the larvae being found in the fall and winter, feeding together with the adults on a fungoid growth which lines the tunnels and which is carefully propagated under the intelligent supervision of the insects. The tunnel made by this borer is first toward the center, then a horizontal gallery is made running part way around the trunk or branch, and at right angles to this a large number of galleries are excavated, running up and down the stem. O. Schneider-Orelli* has traced out the life history in Europe and finds that in Switzerland the females migrate to new trees to found new colonies beginning as early as April 19, and may continue such activity throughout a period of two months, according to climatic conditions. Eggs were found May 10, the majority being laid in late May and ceasing wholly with the beginning of June. The number of eggs laid by a single female varied from 6 to 45; these are usually laid in clusters of six, chiefly at the junctions of the tunnel system, seldom being laid in the blind tunnels. The pupal stage

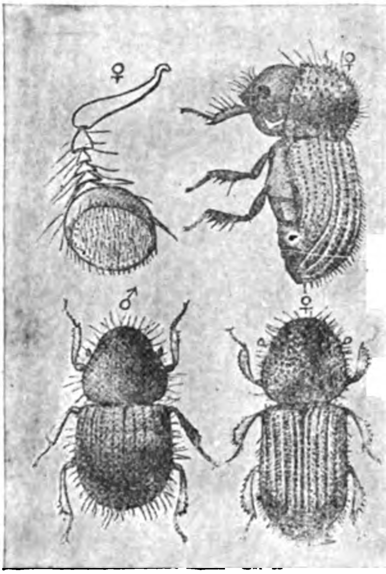

Fig. 13. *Xyleborus dispar:* **male and female imagoes, enlarged; antennae of female more enlarged. After Hubbard, Bul. No. 7, N. S. Bur. Ent., U. S. D. A.**

*Centralbl. Bakter., Paras. and Insekt., 2 Abt. XXXVIII, No. 1-6, 1913, pp. 25-110.

lasts from 10 to 14 days and the young beetles hibernate in the tunnels. According to these observations there is but one generation per year. A species of *Xyleborus*, probably this species, was received from Hudson, O., May 13, 1912. Badly infested trees should be cut and burned in the fall. Healthy trees, if threatened, should be kept thrifty and whitewashed, or kept covered with a carbolized soap paint to repel the beetles and prevent egg laying.

Xyleborus pyri has been recorded from West Virginia and probably occurs in Ohio. It may possibly be identical with *X. dispar*, and is sometimes found associated with it. It enters the green sapwood and heartwood of logs, stumps, injured living trees, and probably healthy trees as well. In food habits, life history and economy, it may be assumed to closely parallel *X. dispar*. Hopkins records for W. Va., adults May 8, 9; larvae, June 1; eggs, May 8, 9.

TWIG BORERS

All of the species previously treated belong in the family Scolytidae, but two other small beetles of another family, with boring habits, are occasionally encountered and require mention. These belong in the family *Bostrychidae*, or Powder Post Beetles.

APPLE TWIG BORER

Amphicerus bicaudatus Say.

This is cousiderably larger than any other species treated in this bulletin ranging from one-fourth to over one-third of an inch in length. It is dark chestnut brown, or almost black in color, and the thorax is roughened in front with minute elevated points. The male also has two little horns projecting forward on the thorax, one on each side, and a tubercle, or thorn-like projection at the hindermost extremity of each wing cover. The adult beetle bores into small apple twigs in early spring, entering close beside a bud and excavating a channel down the pith which may be several inches long. Both sexes enter twigs in this manner, and sometimes may be found in such burrows in winter as well as during the summer. Twigs of pears and cherries, also grape canes are entered and killed in this manner. During the summer, the beetles generally leave these feeding burrows and deposit their eggs in the dead and dying roots of greenbriar or catbriar (*Smilax*) or in the dead shoots of grape.

Twigs containing the beetles or their burrows should be pruned out and burned and, if the beetles are abundant, destroy all catbriar plants and wild grapes to be found in the neighborhood. Some specimens in the Station collection were sent in from Boggs, O., April 5, 1897. They were said to be abundant at that place and time. Some

more recent reports of damage may have been occasioned by this species, but we have no record, confirmed by specimens except as above stated.

RED-SHOULDERED SINOXYLON

Sinoxylon basilare Say.

This blackish beetle is closely related to the preceding, but is considerably smaller, being about one-fifth of an inch long and has a large reddish spot at the base of each wing cover. The thorax is furnished with elevated points and short spines in front. The wing covers make such a sudden declivity downward and backward that they appear to be cut off obliquely inward behind, forming a V with the point headward; each side of the V is armed with three teeth. It injures the stems of grapes by boring into them, also the trunks and branches of peach and apple trees. The grub which develops in dead twigs is much wrinkled, yellowish-white and has the anterior segments much swollen and enlarged. The pale- yellowish pupa is formed within the burrow. Infested canes and twigs should be pruned out and burned and the trunks of threatened trees protected as from other small borers. One record from Wooster, Ohio, March 3, 1899, reared in insectary from hickory twigs. We have also received it from Perry, O., July 8, 1910, in peach, it being reported as seriously injurious.

THE COB-ROT OF CORN

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., NOVEMBER, 1913.

BULLETIN 265

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

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[1]With leave of absence. [2]In cooperation with Weather Service, U. S. Department of Agriculture.

BULLETIN

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Ohio Agricultural Experiment Station

NUMBER 265 NOVEMBER, 1913

THE COB-ROT OF CORN*

By E. G. ARZBERGER

INTRODUCTION

The fungus organism which, in part, initiated the work on this problem was first sent to the Experiment Station by W. J. Wheeler, of Paulding, Ohio, April 12, 1911. He had noted that the cob tissue of some of his stored seed corn, crop of 1910, had become somewhat abnormal; this was partly due to the activity of a fungus which was subsequently identified as belonging to the genus *Coniosporium*.

Some preliminary observations were made on this fungus during the year after it was found. During the fall and winter of 1911-12 the fungus again appeared abundantly on the husked corn. In April, 1912, more extensive observations and investigations were begun, the details of which are set forth in this report.

The chief object of this investigation was to determine whether the fungus in question, *Coniosporium Gecevi* Bubak, found on the ears of field corn is a true parasite or only a saprophyte.

The literature regarding this fungus is not very extensive, and the greater part of it consists of mere mycological descriptions. Saccardo, including those in his 17th volume, has described 82 species of Coniosporium. Some of the descriptions are detailed enough and state whether the species are parasitic or saprophytic, while others are recorded rather incompletely. The nature of the greater number can be judged from the dead or decaying wood or plant tissue upon which the fungus had been found.

Of the 82 species given, 57 are saprophytic, 10 parasitic and 15 are questionable, regarding their nature. These may be saprophytes or facilitative parasites.

*In the fall of 1911 there was prevalent over Ohio a disease or affection of corn which had not previously been observed on so large a scale. The trouble was manifested in a softening and decay of the cob, rendering the grain unmerchantable. The outbreak was so general that great anxiety was felt lest a serious disease of this most important cereal had made its appearance, and in response to request of leading grain dealers and others an emergency appropriation was authorized by the Emergency Board for the study of the outbreak by the Botanical Department of the Experiment Station. This work was assigned by the Station Botanist to Mr. E. G. Arzberger, Assistant Botanist, an abstract of whose report upon it is given in the following pages. A. D. Selby, Botanist.

Lindau, in Rabenhorst's Kryptogamic Flora, describes 40 species, of which 37 are obligate saprophytes, and 3 are parasitic; some of these are questionable, however, regarding their parasitic nature. One species described may be classed as a facilitative parasite.

Jaap and Bubak haxe recently described three other species of Coniosporium, all of which are saprophytic. The greater number of the above have been found in Europe. Spegazzini, in his list of Mycetes Argentinensis of South America, reports four new species, all of which are saprophytic.

If access could be had to the proper herbarium material, it would probably be found that *Coniosporium Gecevi*, described in 1911, had already been described as some other form in America. However, from the most authentic mycological descriptions one may note the general saprophytic nature of this genus. In Rabenhorst's Kryptogamic Flora, Lindau makes this general statement about the entire genus: "The development of this fungus, especially the nature and formation of the conidia, is still unknown, and requires elucidation through cultural examinations. The *greatest number live* as *obligate saprophytes*, yet not without exception, as is shown in *Coniosporium arundis*, which, in its mycelial stage, is found in the living tissue of its host plant."

Bubak,[1] of Tabor, Bohemia, describes in Centrb. f. Bak. u. Infekk. 31: 500-502, 1911, a new species of Coniosporium, found on the cob of corn ears. He sets forth a somewhat detailed description of the fungus and states that the fungus is not a parasite but only a saprophyte which covers the glumes and parts of the kernels, darkens them and can render the corn material slightly less valuable. He proposes the name *Coniosporium Gecevi* Bubak n. sp.

To be positively certain whether the species of Coniosporium, that is associated with our corn, is the same as Bubak had reported from Bulgaria, some specimens were sent to him on February 17, 1912, asking him to compare them with his native material. Similar specimens were also sent to Sydow and Lindau at Berlin and to Saccardo at Padua, Italy. These men were requested to identify the fungus sent, and also to state whether they regarded it as a parasite or a saprophyte.

During the following March replies were received from all four men. Lindau classes it in the genus Epicoccum and says: "It might be possible that this fungus grows first as a parasite and fruits as a saprobytic growth. However, investigation regarding this phase will elucidate."

[1]Einige interessante Pflanzenkrankheiten aus Bulgarien. Von Prof. Dr. Fr. Bubak (Tabor, Bohmen) und Dr. P. Kosaroff (Sofia, Bulgarien). (Referent Dr. Fr. Bubak.) Erster Teil. (Several interesting Plant Diseases from Bulgaria by Dr. Fr. Bubak (Tabor Bohemia) and Dr. P. Kosaroff (Sofia, Bulgaria). First part.) Centrb. f. Bakt. u Infekk. 31: 495-502, plates 2.

Sydow says, "I have found that it belongs to the genus Coniosporium, but I am unable to identify it with any known species so that I believe that it is a new species. I cannot decide the question whether the fungus is a parasite or only a saprophyte, but I am inclined to think that it is a saprophyte."

Bubak states that the fungus sent to him is identical with the one he has described. He sent some of his original specimens, of which the spore measurements and other characteristics agree well with our native material. He says in his letter: "I first received this fungus from Bulgaria in the winter and therefore could not decide with certainty whether it is a parasite or a saprobyte."

Saccardo in his reply states that the fungus is a new species of Coniosporium, but later corroborates the view held by Bubak. He makes no assertion regarding its parasitic or saprophytic nature. These statements show that it is not always an easy matter to decide whether a fungus organism is parasitic or saprophytic.

OBSERVATIONS MADE IN 1911

During the summer of 1911 cultures were made from the various tissues of the ear upon which the Coniosporium is found. These were developed at different intervals during the summer season until inoculations were made in August on a number of corn plants grown in the pathologist's garden. As a result the fungus was found on the check plants as well as those that had been inoculated. Because of too limited knowledge regarding the fungus no exact data could be obtained. Besides this, many unfavorable environmental conditions, not anticipated, led to indeterminate results.

A number of days were spent during November and December examining the husked corn on the Station's fields in regard to this rot. Similar data were obtained from fields in the northwestern and southwestern parts of the State. The results of this work are summarized in Tables I and II. Some observations were also made on normal growing corn during the summer of 1911. No evidence could be obtained of the fungus as being associated, as a pathogenic organism, with the living corn plants. Yet but little assurance was placed in this, for very little was known regarding the nature of the fungus and how it behaves in the plant before it becomes conspicuous enough to be noted by the observer.

The first instance where the fungus was found was on ears of corn, the stalks of which had been cut about 2 weeks before. The tips of undeveloped ears were first affected and as the cob tissue lost its cell sap and the living processes of the cells ceased, the fungus would continue its growth into these parts.

Observations were made during November, December and on through April, 1912. In these observations the Coniosporium was found developed on the shanks, and infrequently some of the inner sheathing leaves of ears were covered with the mycelium and spores of the fungus. No other part of the corn plant could be found which was affected by the Coniosporium; and furthermore, no other species of plants associated with the corn were found affected by this fungus. It was assumed that Coniosporium might live on other plants during the spring and early summer months, which habit would help bridge it over until the corn is in a condition to be affected by it.

Only one specimen of another plant was found that was affected by Coniosporium, that being a head of barley which was dead and dry, having been eaten off by some insect. None could be found after a diligent search on the living barley plants. Here may be noted its saprophytic nature. During May and June a careful study was made of the young corn plants and of grasses and weeds growing with them. The only fungi found were *Pleospora* and *Epicoccum neglectum* on the the dead portions of clover leaves and on some of the dead portions of orchard grass and timothy. The Epicoccum also appears as a saprophyte on old, dead corn ears, leaves and stalks during the early spring after an abundant rainfall. It is of but little economic importance because it attacks those decaying parts which are of no practical value to the farmer.

In noting abnormal stages of young corn plants, the reddened condition, especially of those grown on clover or grass sod, was frequently observed. This, however, was generally due to the injury done by grubs, wire worms and other insects. The wounds serve as portals of entry for soil bacteria, which find their way into the vascular bundles, inhibiting the living processes of the plants and discolored, dwarfed plants are produced. Often, when the physical and biological conditions of the soil are unfavorable, the lower part of the stem of the young plant becomes affected with fungi and bacteria. These will affect the stem and roots and produce sick plants. The real causes for the abnormal conditions produced, subsequent to the dying off of the primary portion of the stem, are rather difficult to ascertain because of the many factors that enter in. All subsequent investigations were carried on in experimenting to determine whether the Coniosporium is a parasite or saprophyte.

METHODS OF WORK

The cultures were all grown on nutrient glucose agar in petri dishes. Fresh cultures were made continually in large quantities during the summer. During the hot weather of the

months of July and August only a few spores were developed by the fungus, but ample growth of mycelium was formed on the culture media. Later, however, the cultures were placed in the ice box, which furnished sufficient coolness for the development of spores on the mycelium. In cooler weather the mycelium grew profusely, forming an abundance of spores within a few days.

Sterile methods, that were best suited, were employed in making inoculations. All wounds were made with a sterile scalpel or needle on tissues that were sterile or had been made sterile by washing with bichloride of mercury. After the fungus had been inoculated into the tissue of the plant the wound was covered over by sterilized paper to keep out all organisms and to let only the inoculated organism be present in the tissue that was treated.

Besides the pure cultures on nutrient media, dilution cultures with distilled water were made and used; cob material affected with Coniosporium was also used. Inoculations were made from day to day when the weather permitted, and usually in the afternoon, when moisture conditions did not interfere with the inoculation process. All plants were labeled with tags dated and numbered consecutively.

Between July 30 and October 17, 1912, 276 inoculations of corn plants were made, laboratory numbers 1,056 to 1,331, inclusive, the work being done on 29 different dates and the inoculating material being placed in the nodes, internodes, roots, brace roots, sheath leaves, shanks, ears, silk and top leaves. Besides these, 40 to 50 inoculations were made on very young corn plants in greenhouse, garden and laboratory; 258 of these inoculations were made with Coniosporium cultures. These inoculations were examined at different dates until November, but no infections of Coniosporium were found from any of them.

On September 19th inoculations of 9 plants, Nos. 1251 to 1259, inclusive, were made of a mixed culture of two or more fungi that were found associated with decaying ears in last year's investigation of husked corn in the field. One fungus is a Diplodia and the other a dark colored organism, which with the Diplodia forms a grayish colored mass. The dark mycelium never has produced any fruiting bodies of any sort. It seems to live symbiotically with the Diplodia which I assume, from a limited knowledge of it, prepares conditions for the growth of the dark mycelial organism. The Diplodia, however, carries out the parasite's nature and brings about the results as found.

Examinations of the inoculated plants were begun on September 12 and contiuued until December, but no evidence was found of any infection by Coniosporium due to these inoculations.

On October 9th a somewhat superficial examination was made of the plants first inoculated with the Diplodia fungus. All nine ears of these plants at this time were beginning to show infection with the fungus. The inoculated ears were covered again with sterilized paper and were not examined again until in November. All the other corn plants, excluding the above nine, in this group, were inoculated with Coniosporium, but no infection took place.

The last examination of these plants was made on November 6th. The corn had at this time all been killed by freezing and the stalks had nearly dried out. The same ears on the plants, numbered from 1254 to 1259, inclusive, showed a good growth of the fungus inoculated in all parts of the ear. Some ears were more affected than others. At this time the white mycelium, apparently of Diplodia, covered considerable of the kernels. The early growth and action of the fungus on the kernels and cob is very similar to that of the Diplodia. Dark mycelial masses are produced that resemble very much the immature fruiting bodies of Diplodia. The dark, heavy-walled mycelium is very different from that of Diplodia. It seems that the Diplodia-like organism acts parasitically and after it has done its work this black colored fungus develops with it and grows as a saprophyte. The relationship of these two fungi appears somewhat complicated and involves a problem requiring further investigation.

LABORATORY EXPERIMENTS

One of the first experiments in this connection was carried on in the laboratory in the following manner: Growing ears of corn, in which all tissues were living, excepting a few portions of the sheathing leaves, were taken from healthy plants in the field. A certain number of these were placed in wire baskets and sterilized in the autoclave for one hour at 15 pounds steam pressure for two successive days. This was done to make sure that every particle of corn tissue was killed, and that nothing placed thereupon could grow or live as a parasitic organism. After their removal from the autoclave, under the best sterile conditions afforded, the ears were variously inoculated with fresh and pure cultures of Coniosporium. The inoculated specimens were then placed in large, sterilized battery jars, kept moist with sterilized filter paper; these in turn were covered with large sterilized bell jars. A sufficient amount of moisture was furnished by the sterile water poured upon the filter paper and into the bottom of the jars.

The same day similar inoculations were made on ears of living corn in the field and on ears brought into the laboratory, which were placed as checks in battery jars under bell jars without cooking.

After eight days the ears which had been cooked in the autoclave and subsequently inoculated with the pure cultures presented an abundant growth of mycelium and spores. The fungus had penetrated through the cob tissue, passing out and surrounding the kernels and filling up the cavities between the kernels and rows.

The living specimens under the bell jars, and those in the field which were inoculated the same day, showed no development on the living kernels and cob tissue, when also examined eight days after their inoculation. Plenty of moisture was present for the living and dead ears in both sets of experiments in the laboratory, a factor which was somewhat deficient with specimens in the field. However, this was not a general missing factor, inasmuch as the fungus did not develop on and in the living tissue when it had an abundance of moisture. Apparently the living protoplast of the kernels and cob tissue presents unfavorable conditions for the development of this fungus when placed there in its most active stage of growth. Numerous similar examples are also afforded by the inoculations made on the living tissues of the corn in the field during the summer. Examination and reexamination again and again showed that no infection had taken place in the live tissue; whereas, in the dead tissue, killed around the wound by the method of inoculation, there developed a good growth of the fungus. If enough moisture was present a good growth of mycelium would be produced on the tissue as it gradually died back from the wound. In this dead tissue, and especially in that of the cob, the fungus produced its normal amount of spores, which were viable and would again produce the fungus when placed on culture media.

Results quite similar to the preceding were also obtained by using last year's ears that had been naturally affected with the Coniosporium in the field. These were placed in a moist chamber, after washing off with bichloride of mercury (2 parts to 1,000 of water) some of the superficial spores of other fungi. After ten days or more the fungus had developed in the cob and about the kernels, giving the entire ear a somewhat grayish appearance, providing other fungi did not predominate in growth. However, it is very difficult to get a pure growth of Coniosporium under these conditions, because other forms, like Fusarium, Rhizopus, Penicillium, Aspergillus and Cephalothecium, will finally develop on the unsterilized material, thus making it difficult with so many of these other organisms to determine just how much Coniosporium would develop after having naturally become affected, and subsequently placed under these somewhat abnormal conditions.

Further evidence, showing that Coniosporium grows as a saprophyte, is deduced from the following experiment: Pure cultures of the fungus were placed on sterilized cellulose prepared from good filter paper. This had been digested with concentrated hydrochloric acid and subsequently washed free from the acid and sterilized in small Erlenmeyer flasks, from which it was poured into large petri dishes. Whenever the cellulose was too dry, sterile distilled water was added to make it loose as well as moist.

At ordinary room temperature, 16 to 18° C., the fungus started its growth quite readily and after 20 days the surface of the cellulose in the 100 mm. petri dishes was literally overgrown with the mycelium of the fungus. Later the mycelium penetrated through the entire mass of cellulose as well as covering the surface, which was black with spores.

With no other material than pure water and cellulose on which to develop, the readiness and length of time that Coniosporium will grow on this, certainly sets forth some evidence that it does not require living protoplasm in or on which to find the necessary nutriment for its development. Very few, if any, of the parasitic fungi can be made to develop to any great extent on pure water and cellulose alone. The fact that it can obtain food elements from these two compounds shows that it is not concerned at all during its living processes with living protoplasm or living cells to serve it as a host.

This fungus can easily be grown on other forms of cellulose. Pieces of pith, taken from the stems of elder and corn stalks, were placed in large test tubes with a small amount of distilled water. After sterilizing these in the autoclave the pith was inoculated with pure cultures of Coniosporium. A sufficient amount of water was left in the bottom of the tube to keep the pith moist. Growth of the fungus took place immediately and within eight days a great many of the pieces were penetrated and covered by the gray colored fungus. In this case it is clearly shown how the fungus affects the thin-walled parenchymatous cells, rather than the sclerenchyma cells that make up a part of the vascular bundles, the cortex of the corn stalk and a large portion of the hard material of the corn cob.

Furthermore, the readiness with which this fungus develops on the various culture media by transferring methods tends toward showing that this fungus presents no parasitic tendencies. Fungi that are known to be true obligate parasites are not easily changed in their nature from a parasite growing on living plants to a saprophyte growing on artificially prepared culture media. It was found that *Coniosporium Gecevi* developed on all the media that

were tried. It developed more readily and more luxuriantly on media that contained an abundance of grape sugar and some form of nitrogen. The following media, titrated to +1 to +1.5, were used and growth was obtained on all of them; nutrient glucose agar, corn meal agar, lima bean agar, plum decoction agar, Riedemeister's and Dr. Moore's synthetic media and sterilized wheat bread, besides the cellulose and pith already mentioned.

The fact that the Coniosporium grows so readily on some of the media and also that it grows on all the media, no special method or medium being required to make it grow as a saprophyte, is evidence of its saprophyte nature. On the other hand, obligate parasites, such as Rusts, Smuts, Helminthosporiums, and Peronosporas, are grown only with great difficulty on artificial media, because of the selective properties of the organisms and their obstinate nature in being changed to saprophytes. These obligate parasites affecting the corn plant have been found by investigators to offer many difficulties in growing them artificially.

Another experiment was performed with small corn plants growing in the greenhouse. The plants were from 10 to 15 days old, 3 to 4 inches high and growing vigorously, thus possessing a considerable amount of meristematic tissue which is frequently more susceptible to infection by fungus organisms. The soil covering the roots and lower part of the stem was removed, pure cultures of Coniosporium were abundantly applied, and the soil was replaced. These plants were in no way affected or inhibited in their growth when compared with the check plants growing along with them. A similar experiment was carried out on plants grown in the garden. No symptoms that the plants were being affected in any respect could be noted on any of these.

The results from these experiments further support the conclusion that the Coniosporium organism is not a parasite, but merely a saprophyte.

Besides the experimental work in the laboratory, greenhouse and garden plots, observations were made on the corn in various parts of the State and in local fields of farms adjoining the Station. Of the many thousands of corn plants thus observed and studied no plant was found where Coniosporium was active as a pathogenic organism. Again, if this organism had been the cause of serious disease heretofore, it is presumed that it would not have escaped the detection of mycologists and plant pathologists during the past years. It certainly could not have developed *de novo* or through some mutating process during the past few years.

Judging from the extent to which this fungus is found, it seems probable that it has been indigenous with the corn in this country and only the favorable weather conditions brought about its abundance in the crop of 1911.

ECONOMIC SIGNIFICANCE OF CONIOSPORIUM

Since this fungus, as ascertained from investigational evidence, cannot be considered as the cause of disease of the living corn plant, it has, nevertheless, an economic importance, for it does render the kernels less valuable, as do the mucors, penicillium, aspergillus and other similar forms. It is true that the mycelium penetrates the various cob tissues and the lower portion of the kernel, such as the funiculus. Besides the basal portion, it may cover over as much as the lower half of the kernel. But it cannot be maintained that Coniosporium injures the young plant or embroyo in the kernel. The conditions which are favorable for the development of the fungus have previously been unfavorable to the living processes in the young plant, which is dead before the fungus begins its saprophytic action on that portion of the kernel.

The injury done by the Coniosporium, aside from that done to the cob tissue, is relatively small, comparing ear with ear of those affected with other fungi which destroy the entire kernel and render its food content almost valueless.

In regard to its effect on the feeding value of the corn, farmers who fed their cattle with corn affected by Coniosporium claim that no abnormal effects could be noted on animals fed with such corn. Several farmers stated that they fattened stock on just such corn. It is difficult to have corn affected only with the Coniosporium, and when symptoms of disease in the animal did occur, it may have been brought about by other forms of fungi that are known to be the cause of diseases in animals to which corn is fed.

The effect of cob-rot on the ears of corn after maturity would appear analogous to certain timber-rot fungi which attack the heart or other portions of the tree trunk, while not attacking the living portions of the tree, although the heartwood be still enclosed within the cylinder of the living layer. The analogy here suggested is that the economic value of the corn attacked by cob-rot is impaired, and in even greater proportion than the economic value of the timber destroyed by timber-rots. While we can not call such timber-rots of pine, oak, etc., diseases of the living oak or pine trees, we recognize their economic significance as timber-rots. In a similar sense the cob-rot will continue to be recognized as an impairment of the matured corn ears whenever prevalent.

OTHER FUNGUS DISEASES OF CORN

A diseased condition of the corn was first noted about August 14th in the variety plots and later in the ensilage fields of the Station. The most apparent symptoms in the leaves are quite like those caused by the early stages of rust infections. At first the spots are quite small and about a millimeter in diameter. Later these may enlarge to circular spots a centimeter across and frequently several of the small spots merge and form one large spot. These regions in the leaf are quite translucent and when all the leaves are affected it gives the plant a somewhat mottled appearance when observed by transmitted light. Photographs of the affected leaves will hardly present the spots in a surface view that will set forth the actual and essential features. The spots will after a time become brown, dry and hard. The pressed specimens will show this. From the incomplete study made, it appears that the mesophyl of the leaf is most affected but the vascular system is quite resistant and therefore very few leaves were found collapsed from the lack of water. It is difficult to find the early stages of this infection. A microscopic examination will reveal spores of rust bacteria and large spherical bodies and swarm-spores of this fungus which Barrett calls *Physoderma zeae maydis*. It is still a question whether this fungus in its swarm-spore stage does the entire injury, for the many cultures, made from the diseased parts, revealed two kinds of bacteria, one forming a white colony and the other a yellow. No growth of the fungus was secured although about 300 plates of cultures were made on nutrient glucose agar. Inoculations were made with the two bacterial forms but no symptoms were obtained. I am of the opinion that the bacteria are only secondary intruders.

A considerable number of leaves were pressed and preserved in good condition but it is quite difficult to find many of the resting spores in the dry material. The best and only method for the study of this is with the fresh material.

This fungus trouble was reported by Barrett[2] at the Science Meeting held at Cleveland last December. The illustrative material displayed by him resembles the material I found. I sent him some specimens and regarding them he says: "As far as I am able to make out they bear the same organism as found here and that I described at the Cleveland meeting."

Although the symptoms of the disease are very conspicuous, yet little is known about the real cause as to how they are produced. Therefore, careful isolations and inoculations must be made before much can be definitely stated about it.

[2] *Physoderma zeae maydis* Shaw, in Illinois, by J. T. Barrett.

TABLE I: Fungi found at husking, Oct. 20-30, 1911, on corn of different varieties.

Variety of corn	Total No. of ears per shock	No. affected with Coniosporium	Per cent	No affected with Diplodia	Per cent	No. affected with Fusarium	Per. cent	Total percent affected
1. U. S. No. 78	186	46	24.7	0	0	1	0.6	25.3
2. Funk's Yellow Dent..	154	44	28.6	2	1.3	0	0	29.9
3. " " " ..	141	44	31.2	0	0	0	0	31.2
4. " " " ..	148	29	19.6	2	1.3	0	0	20.9
5. Stickney's Flint......	170	147	80.6	2	1.2	0	0	81.8
6. " "	202	176	87.1	0	0	0	0	87.1
7. " "	148	138	93.2	0	0	0	0	93.2
8. Check Clarage........	175	87	49.7	3	1.7	1	0.6	52.0
9. " "	177	53	29.8	2	1.1	0	0	30.9
10. Clarage x White Cap.	204	69	33.8	3	1.5	0.	0	35.3
11. " " " ...	172	47	27.3	0	0	2	1.2	28.5
12. Cranz's White Cap....	153	78	50.9	0	0	0	0	50.9
13. " " "	149	41	27.5	0	0	1	0.7	28.2
14. Check Clarage........	165	57	34.5	0	0	1	0.7	35.2
15. Silver King..........	180	27	15.0	1	0.55	0	0	15.5
16. " "	175	68	39.0	1	0.6	0	0	39.6
17. Untested Seed...	123	14	11.4	0	0	0	0	11.4
18. " "	151	26	17.2	2	1.3	0	0	18.5
19. " "	189	74	39.1	0	0	5	2.6	41.7
20. Reid Zehring..........	164	33	20.1	0	0	0	0	20.1
21. " "	154	39	25.3	0	0	0	0	25.3
22. Strain No. 84..........	132	36	27.4	1	0.8	0	0	28.2
23. " " 84.	136	32	23.5	1	0.8	0	0	24.3
24. " " 84.........	141	22	15.6	0	0	1	0.7	16.3
25. " " 84.........	132	26	19.7	2	1.5	0	0	21.2
Average..................			34 87		1.13		1.0	35.15

TABLE II. Fungi found at husking in November, 1911, on corn planted at different dates.

Time of planting	Total No. of ears per shock	No. of Unaffected ears	Percent	No. affected with Coniosporium	Percent	No. affected with Diplodia	Percent	No. affected with Fusarium	Percent	Total percent affected
1. April 29, 1911.	184	150	81.5	31	16.8	3	1.7	0	0.	18.5
2. " " " .	159	126	79.4	29	18.2	3	1.9	1	0.5	20.6
3. " " " .	141	109	77.4	30	21.2	0	...	2	1.4	22.6
4. May 7, 1911....	170	128	75.3	37	21.8	3	1.7	2	1.2	20.6
5. " " "	181	148	81.8	33	18.2	0	0.	0	0.	18.2
6. May 16, 1911..	180	144	80.+	33	18.3	1	.55	2	1.1	18.96
7. " " " ..	145	125	83.5	20	14.4	.	....	3	2.06	16.46
8. May 26, 1911..	143	129	83.3	22	15.3	2	1.4	.	....	16.7
9. " " " ...	159	128	80.5	29	18.2	.	....	2	1.3	19.5
10. June 6, 1911 ..	158	131	83.0	26	16.4	1	.6	.	....	17.0
11. " " " ...	135	100	74.1	35	25.9	.	....		....	25.9
12. " " " ...	175	154	88.1	19	10.8	.	....	2	1.1	11.9

Table II gives the percentage of the different fungi found at husking on corn planted on different dates in 1911. No Coniosporium was found affecting the corn before or during the time of cutting. With the exception of Diplodia and Fusarium, all Coniosporium developed on the ears in the shock during the moist weather.

There were only 3 shocks of the different plantings, hence no larger number of observations could be obtained. But from the limited observations that could be made on the small field, the data

show that there is no difference in the total amounts of fungi occurring on the corn planted at different times in spring. The Coniosporium was found just as abundantly on the early as on the late plantings. The weather conditions are the chief factors in determining the amount of Coniosporium that will develop on ears of corn.

TABLE III: Fungi found at husking, Oct. 24 to Nov. 14, 1912 on corn of different varieties.

Variety of corn	Total No. of ears per shock	No. affected with Coniosporium	Percent	No. affected with Diplodia	Percent	No. affected with Fusarium	Percent	Total percent affected
1. Boone Co. White......	130	1	.76	.	...	1	.76	1.5
2. " " "	145	2	1.40	.	...	.	....	1.4
3. " " "	152	..	.....	.	...	1	.6	.6
4. " " "	136	..	.....	1	.7	.	....	.7
5. " " "	131	..	.....	.	...	1	.76	.8
6. " " "	111	..	.....	1	.9	.	....	.9
7. Clarage...............	157	5	3.20	.	...	.	....	3.2
8. "	140	3	2.10	.	...	1	.7	2.8
9. "	141	4	2.80	.	...	3	2.1	4.9
10. U. S. No. 182..........	154	..	.....	.	...	.	....	0.
11. " " " "	126	..	.....	.	...	.	....	0.
12. " " " "	148	..	.....	.	...	.	....	0.
13. Cook's Original.......	145	..	.....	.	...	.	....	0.
14. " "	138	..	.....	.	...	.	....	0.
15. " "	132	..	.....	.	...	.	....	0.
16. Cook's No. 75..........	187	9	4.80	.	...	1	.5	5.3
17. Check Clarage........	160	6	3.80	2	1.3	.	....	5.1
18. Early Leaming (Frost)	181	10	5.50	.	...	5	2.7	8.2
19. Early Leaming.......	180	31	10 70	1	.6	.	....	11.3
20. Untested Seed........	256	6	2.30	.	...	5	1.9	4.2
21. " "	226	3	1.30	.	...	4	1.8	3 1
22. " "	203	4	1.90	.	...	3	1.4	3.3
23. " "	197	9	4.60	.	...	3	1.5	6.1
24. Check Clarage........	113	11	9.80	.	...	.	....	9 8
25. " "	129	4	3.10	.	...	2	1.6	4.7
26. " "	171	7	4.10	.	...	7	4.1	8 2
27. " "	144	4	2.80	.	...	6	4.1	6.9
28. " "	121	..	.....	.	...	1	.8	.8
29. " "	110	8	7.30	.	...	2	1.8	9.1
30. Tested Seed...........	180	7	3.90	1	.5+	4	2.2	6.6
31. " "	181	6	3.30	.	...	1	.5+	3.8
32. " "	52	12	23.00	.	...	2	3.8	26.8
33. Untested Seed........	55	5	9.09	.	...	4	7.2	16.29
34. Dark Co. Mammoth...	83	15	18.07	.	...	.	....	18.07
35. " " " ...	90	14	15.50	.	...	2	2.2	17.7
36. " " " ...	71	16	22.50	.	...	.	....	22.5
37. Dark Co. Mammoth...	81	10	12.30	2	2.5	.	....	14.8
38. " " " ...	221	3	1.30	.	...	4	1.8	3.1
39. Leaming.............	78	20	25.60	.	...	2	2.5	28.1
40. "	195	10	5.20	.	...	3	1.5	6.6
41. "	108	17	15.70	1	.9	2	1.8	18.4
42. Clarage new..........	126	2	1.60	.	...	.	....	1.6
43. " "	158	13	8.20	.	...	.	....	8.2
44. " "	201	9	4.40	.	...	.	....	4.4
45. " "	232	11	5.70	.	...	2	.8	6.5
46. Clarage old (short ear)	132	10	7.60	.	...	.	....	7.6
47. " " " "	201	6	2.90	.	...	5	2.4	5.3
48. " " " "	156	9	5.70	.	...	2	1.3	7.0
49. " " " "	223	16	7.20	.	...	9	4.0	11.2
50. " " " "	187	6	3.20	.	...	2	1.0	4.2
51. " " " "	230	8	3.50	.	...	6	2.6	6.1
52. " " " "	151	14	9.20	.	...	.	....	9.2
53. " " " "	182	14	7.60	1	.5	7	3.8	11.9
54. " " " "	216	8	3.70	.	...	4	1.8	5.5
Average..............			6.90		.98		2.07	7.79

The corn in shocks numbered 10-15 inclusive in Table III was very green when it was cut and contained considerable moisture in

the stalks and sheathing leaves, while all the cob tissue and kernels contained considerable cell sap. This greenness or presence of much living tissue accounts for the ears not being affected by any fungi. Not all the shocks of this variety were examined and there may have been some that were affected with Diplodia.

The percents of corn found affected with Coniosporium in 1912 range from 0 to 26.6, which is relatively lower than that of the crop of 1911, where the range found is 11.4 to 93.2 percent. The average of the total affected plants, as found in 1912, is 6.9 percent, while that of 1911 is 34.8 percent, showing that the crop was considerably more affected in 1911 than in 1912.

In Table III the data numbered from 32-37 were taken from husked shocks in a part of the field where grub worms had done considerable injury during the entire summer and the stalks, with partly developed ears, died very readily and the ears soon afforded enough dead tissues for the Coniosporium to begin its growth. Following this, on Nos. 38-54, the percents are somewhat lower, indicating a better and more normal growth of corn in the same rows of the field, but there was inhibition of growth, apparently by external factors.

SUMMARY

Of the many thousand living corn plants examined none were found that were injured or diseased with *Coniosporium Gecevi.*

Inoculation experiments were carried on from July 30th to October 15th, 1912, a period of 78 days, during which time all stages of corn plants were utilized for the many different methods of inoculations that were used to duplicate or carry out such as might occur under natural conditions.

No infections were obtained on the living corn plants from the 276 inoculations made in the field. Besides these the 40 to 50 inoculations made on very young corn in greenhouse, garden and laboratory presented no evidence of infections.

Eighteen inoculations, made with an unknown fungus or fungi (probably Diplodia and another organism), produced good infections and diseased ears. Further detailed data is needed on these organisms, before more definite statements can be made.

Field and laboratory tests indicate that *Coniosporium Gecevi* develops and acts as an obligate saprophyte, and therefore cannot be considered as the cause of a disease.

Coniosporium has an economic significance in that it destroys the cob tissue as a saprophyte; its effect on the kernels is rather limited when compared with the injury of Diplodia, Fusarium and other fungi.

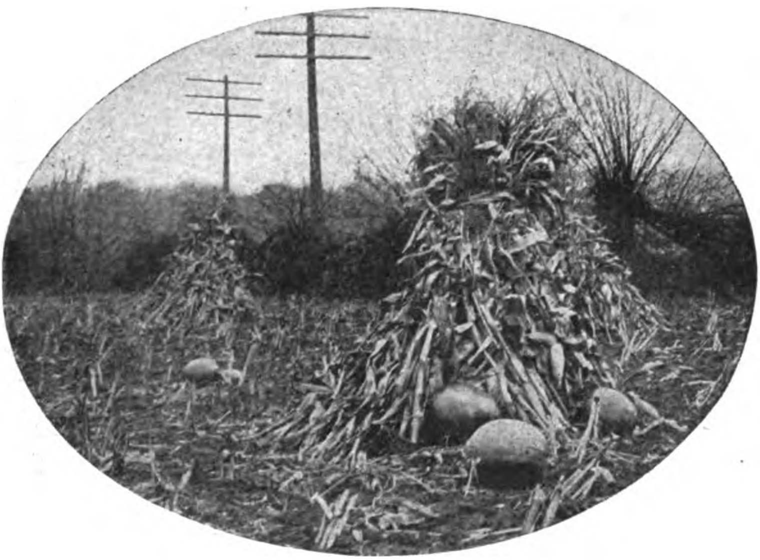
LABOR COST OF PRODUCING CORN IN OHIO

OHIO Agricultural Experiment Station

IN COOPERATION WITH THE OFFICE OF FARM MANAGEMENT
U. S. DEPARTMENT OF AGRICULTURE

WOOSTER, OHIO, U. S. A., DECEMBER, 1913

BULLETIN 266



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OHIO AGRICULTURAL EXPERIMENT STATION

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THE AGRICULTURAL COMMISSION OF OHIO

Columbus

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CONTENTS

ILLUSTRATIONS

ɓ# BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 266 DECEMBER, 1914

LABOR COST OF PRODUCING CORN IN OHIO

A study conducted jointly by the Office of Farm Management, Bureau of Plant Industry, United States Department of Agriculture, and the Department of Cooperation, Ohio Agricultural Experiment Station

By L. H. GODDARD AND W. L. ELSER

During the decade 1900-1909, the average annual production of corn in Ohio was 3,014,607 bushels.* On account of the importance of this crop and the extent to which it is grown throughout the state, it is essential that we know what it costs to produce it, and what are the profits resulting from its production. Owing to the many factors and uncertainties in its production, it is quite difficult to arrive at an accurate cost, but on the basis of nearly 200 fields with a total of more than 2,000 acres, representing 23 counties of the state and with the records extending over a period of seven years, fairly accurate conclusions, at least regarding the labor cost, may be drawn.

In determining the cost of production it is essential that all the labor, whether man or animal, and whether performed by the operator and his family or by hired help, be taken into consideration. While this is perhaps the most important factor in the cost of production, yet it is only one of many. The following outline shows the factors that go to make up the total cost of production.

(1) Labor { Man { Hired; Operator and his family } ; Beast }
(2) Land rental—or the interest and taxes on the amount invested in the land
(3) Machine rental—or the machinery cost of implements used in producing a given commodity—consisting of:
   Annual depreciation—determined from the inventories.
   Repairs { Labor—obtained from the labor reports. ; Cash—obtained from the financial accounts. }
   Interest on the average capital invested in the implement.
   Taxes and insurance on the implement.

*From the reports of the Ohio State Board of Agriculture.

(4) **Supplies**—such as seed; twine; fuel for shredding, silo filling, etc.
(5) **Cash rental of machines and crew**—such as $1.25 per hour for silo filling.
(6) **Fertility**—a proportion of the value of manure, fertilizer or lime applied.
(7) **Interest**—on the cost until the enterprise yields a return.
(8) **Overhead cash expense**—items which cannot be charged to any particular enterprise, but which are prorated among all the enterprises at the end of the year. In many cases a number of small amounts, each of which could be charged directly to some enterprise, have been reported under one head such as, "blacksmithing," "hardware," etc. When they were reported in this manner it was necessary to charge the amount to "General Farm." Other examples of general farm expense are: admission to corn shows and county or state fairs; farm papers; telephone rent; stationery, etc.
(9) **Insurance**—on growing crops against plant diseases, insects, hailstorms and other weather conditions.

The first three items in the foregoing should be found in every crop enterprise, while the fourth and eighth are very common. The item "storage charge" or the rental on the buildings required to store the crop, has not been included in the foregoing outline, for the reason that it is not considered an item in the actual cost of production, but is more properly an item that should be charged against the storage of the crop after it has been harvested, and depends somewhat on the management of the farm and the disposition made of the crop. Since the labor required to produce the crop is of such importance and is so frequently overlooked or underestimated in determining the cost of crop production, an attempt is made in the following pages to discuss some phases of that factor alone.

DEVELOPMENT OF THE INVESTIGATION

The work of collecting the data, on which this bulletin is based, had its conception with the Agricultural Students' Union. Since 1905 the investigation has been prosecuted by the Department of Cooperation of the Ohio Experiment Station, and since 1907 it has been conducted in cooperation with the Office of Farm Management, U. S. Department of Agriculture. In 1905 two cooperators were keeping the labor records on their farms and their first records were of such a nature that it was possible to use them in the preparation of this bulletin. These two men are still keeping records. The number of cooperators keeping similar records has varied from year to year. From the map (Figure 1) on page 87 it will be seen that the various sections of the State have been fairly well represented.

Since July, 1909, the work has been under the supervision of Mr. W. L. Elser. Prior to that date it was in charge of Mr. M. O. Bugby of this Department, to whom the writers wish to acknowledge the great value of the records maintained by him from the beginning of the work in 1905 until he turned it over to others.

Acknowledgements are also due to Messrs. H. M. Dixon and M. R. Cooper, formerly of this Department, and to Messrs. Van Over, Brown and Musser of this Department, for the valuable service they have rendered in connection with this work.

The writers also wish to express their appreciation of the hearty cooperation the many farmers have shown by the excellent condition in which they sent in their records.

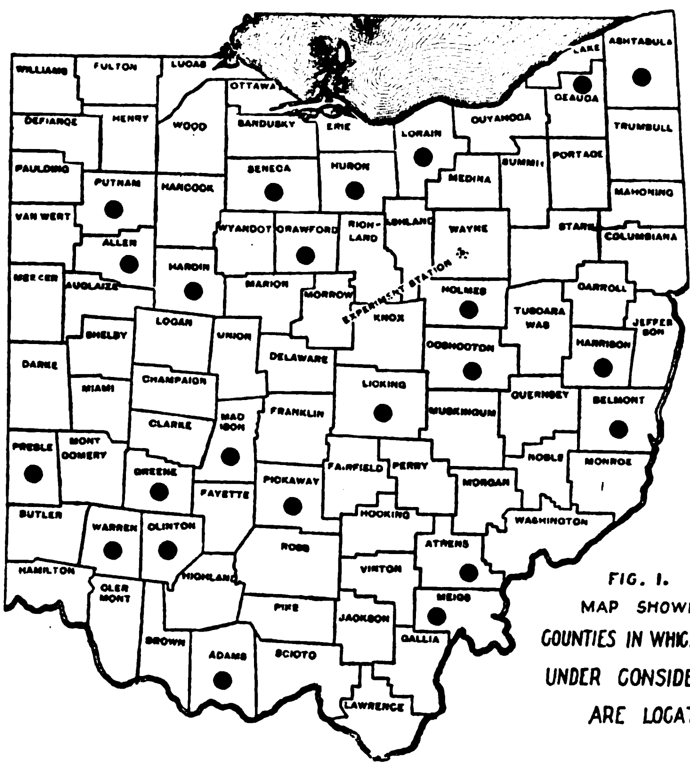

FIG. I.
MAP SHOWING
COUNTIES IN WHICH FARMS
UNDER CONSIDERATION
ARE LOCATED

Daily Time Sheet of..Farm.

In cooperation with
O. A. E. S. and U. S. D. A.
In Farm Management Investigations.

Make all records on day work is done.

Day of week.. Date..

Man Hours	Horse No.	Horse Hours	Field	Kind of Work—*Give kind and size of implement used and area covered or amount of work done. When an operation is finished, so state.*
4.30				
5.00				
5.30				
6.00				
6.30				
7.00				
7.30				
8.00				
8.30				
9.00				
9.30				
10.00				
10.30				
11.00				
11 30				
12.00				
12.30				
1.00				
1.30				
2.00				
2.30				
3.00				
3.30				
4.00				
4.30				
5.00				
5.30				
6.00				
6.30				
7.00				
7.30				
Total Hours				

....Workman.

Wage ....

No. Meals ....

Give below kind, amount and value of seed sown, fertilizer used, manure hauled, material used in any operation (such as building fence, etc.) and crop yields (both grain and roughage). Also give source of material, area or portion of field affected and any notes regarding weather, crops or stock, which may be of interest or value.

....

....

Made out by..

Fig. 2. Form used in collecting the data.

METHOD OF COLLECTING THE DATA

The data have been collected quite largely by correspondence, supplemented by visits for the purpose of taking inventories, measuring fields, etc. Figure 2 shows a time sheet such as is used in obtaining the daily labor reports. These sheets are bound in convenient pads and are furnished each cooperator free of charge. In return he makes out the records for each day in duplicate, sending the original to the Experiment Station at the end of the week and retaining the duplicate for his future reference.

From this figure it is manifest that all the labor performed on the farm during the day is accounted for. This bulletin, therefore, is the first of a series, others of which are now in process of preparation, concerning the various farm crops and enterprises, which were embodied on the farms under consideration. This form of labor record is not recommended as being the only workable method or the form best adapted for use by those wishing to keep their own records. It has, however, proved to be a very satisfactory form for correspondence use from an investigational standpoint, though even here it is not infallible. In many cases, for instance, it has been impossible to obtain the actual number of acres covered in any one operation, such as harrowing or discing. However, this is readily overcome by dividing the total time for all the operations of a similar nature by the acreage of the field. This gives the time per acre for any class of operations, and it is this division which later on gives rise to the fractions of hours other than those ordinarily reported on the daily time sheets. This division also gives rise to combinations of operations which have arbitrarily been termed "Fertilization," "Care of Seed," "Preparation of Seed Bed," "Planting," "Cultivating," "Harvesting," "Miscellaneous Labor," and "General Farm Labor." In referring to these combinations they will hereafter be designated as "Partial Items."

In this publication the term "Fertilization" is used to include all the time of applying manure, mixing and applying fertilizers, and applying lime. Though it is undoubtedly incorrect to charge all of the time of applying manures etc., to the first crop, yet owing to the lack of an authoritative decision in this country regarding the residual effect of manures etc., we have so charged the time for applying in each of the succeeding tables and charts. "Care of Seed" refers to the time required for selecting, storing, testing, shelling, etc., of the seed corn used. The "Preparation of Seed Bed," "Planting," "Cultivating" and "Harvesting," each includes all of the various operations necessary for that particular "Partial Item." "Miscellaneous Labor" includes all labor on corn that does

not regularly fall in any of the foregoing partial items. Inspecting the crop, looking up help for husking, etc., would be examples of what should come in this class. The "General Farm Labor" is labor performed during the year which cannot be charged directly to any particular enterprise at the time the work is done, but must be carried until the end of the year and then prorated or distributed among the various enterprises in proportion to the amount of work done on each. Examples of such labor are: attending public sales, institutes or fairs; farm correspondence and records; mowing weeds along fences and roadsides; cleaning up buildings, etc.

The amount of time devoted to "Fertilization," "Care of Seed," "Miscellaneous and General Farm Labor" varies greatly with individual men and even on different fields operated by the same man. Since this variation is due more largely to individuality than to any other influence these partial items have not been shown in Tables XI, XII and XIV on pages 101, 106, 112, nor in Figures 4, 5, 7, 8, 9, 10 and 11, but the amounts given for the totals include these partial items as well as those shown by those tables and charts.

HOURS VS. DOLLARS AND CENTS

In the tables presented in this Bulletin it will be noted that the cost is referred to more frequently in terms of hours than of dollars and cents, for the reason that the cost of labor varies in different sections and under different conditions. The following, and many similar questions, which form the basis of future study, must be answered before we can attempt to put a valuation on the hours of labor that would be comparable in various sections. What is the value of the board, the laundry work done, or the "horse-keep" furnished the laborer who lives in the home of the operator, or the value of the house and garden, wood, meat, milk, etc., furnished the laborer who boards himself? Does the rate of wage include these? Is the operator's wage the same as that of the hired man? How much does it cost to keep a horse per year, and what is the rate per hour of horse labor? Even with this information it is doubtful if the labor cost, expressed in dollars and cents, has as much significance as when expressed in the terms of man and horse hours. However, in some cases it has been necessary to express the cost of labor in dollars and cents, and in such cases the rates of sixteen cents per hour for man labor and eight cents per hour for horse labor have been assumed. While these rates have been assumed in order to make the records comparable, still they can scarcely be considered as being unjust. Table I, published in the December 1910 Bulletin of the Ohio State Board of Agriculture, shows the average wages paid farm hands in 1,056 or more than three-fourths the townships in Ohio.

TABLE I. Rate of wages paid farm laborers. Gathered and returned by official correspondents of the Ohio Department of Agriculture.

Counties	No. townships reported	What is average wage paid to farm hands			
		By day with board	By day without board	By month with board	By month without board
Adams	11	$1.00	$1.25	$17.55	$22.90
Allen	12	1.23	1.63	21.57	30.25
Ashland	10	1.45	1.71	23.46	30.00
Ashtabula	18	1.34	1.68	22.53	30.43
Athens	8	1.08	1.49	20.29	29.20
Auglaize	12	1.40	1.69	21.89	30.38
Belmont	14	1.12	1.48	20.10	27.60
Brown	10	1.00	1.45	20.64	26.78
Butler	11	1.09	1.53	21.64	30.00
Carroll	10	1.23	1.68	22.73	30.00
Champaign	10	1.28	1.60	22.30	28.33
Clark	5	1.12	1.45	22.20	30.00
Clermont	9	1.08	1.43	19.27	24.88
Clinton	8	1.07	1.53	19.25	25.71
Columbiana	14	1.28	1.73	22.53	36.42
Coshocton	14	1.19	1.65	21.31	30.61
Crawford	16	1.46	1.95	23.10	33.08
Cuyahoga	9	1.38	1.89	23.80	37.29
Darke	14	1.26	1.68	21.27	31.33
Defiance	8	1.22	1.64	22.75	29.60
Delaware	15	1.31	1.72	19.69	27.93
*Erie	10	1.40	1.67	23.91	33.55
*Fairfield	16	1.25	1.65	21.89	30.43
Fayette	7	.86	1.14	19.94	24.71
Franklin	17	1.15	1.51	22.10	30.81
Fulton	8	1.53	1.93	24.38	33.80
Gallia	8	.94	1.22	19.45	25.33
Geauga	14	1.37	1.85	24.60	34.31
Greene	10	1.12	1.45	21.56	32.33
Guernsey	14	1.08	1.47	19.75	28.37
Hamilton	9	1.19	1.58	21.43	31.29
Hancock	16	1.31	1.76	22.06	31.40
Hardin	12	1.27	1.67	21.77	30.73
Harrison	14	1.16	1.60	21.23	30.78
Henry	13	1.30	1.64	22.29	32.09
*Highland	20	1.03	1.34	19.43	26.45
Hocking	7	1.03	1.38	21.60	29.00
Holmes	9	1.23	1.58	21.80	30.83
Huron	16	1.55	2.02	23.47	32.33
Jackson	7	.96	1.27	18.00	25.40
Jefferson	13	1.16	1.59	20.77	28.46
Knox	17	1.29	1.68	21.94	30.38
Lake	7	1.38	1.93	22.28	36.00
Lawrence	9	.83	1.11	19.90	26.22
*Licking	28	1.20	1.63	20.70	28.33
Logan	16	1.32	1.55	20.22	25.00
Lorain	15	1.34	2.00	25.42	35.86
Lucas	10	1.35	1.75	22.90	34.44
Madison	9	1.02	1.29	21.90	28.66
Mahoning	10	1.23	1.70	24.55	33.71
Marion	13	1.48	2.02	23.60	32.14
Medina	11	1.48	1.75	23.82	32.44
Meigs	10	.90	1.25	18.78	29.71
Mercer	12	1.38	1.77	24.80	31.81
Miami	9	1.36	1.72	21.72	26.28
Monroe	15	1.06	1.46	16.29	24.78
Montgomery	11	1.18	1.53	21.31	30.29
*Morgan	17	1.04	1.48	19.50	24.32
*Morrow	18	1.33	1.80	22.72	29.61
Muskingum	22	1.13	1.57	19.96	29.27
*Noble	16	1.20	1.37	18.76	29.17
Ottawa	7	1.35	1.80	23.58	35.00
Paulding	9	1.32	1.92	21.80	32.87
Perry	13	1.13	1.69	24.46	33.73
Pickaway	14	.91	1.20	20.73	27.70
Pike	8	.92	1.14	19.50	26.87
Portage	13	1.48	1.80	24.60	36.50
Preble	12	1.31	1.65	24.36	29.40

TABLE I — Continued Rate of wages paid farm laborers. Gathered and returned by official correspondents of the Ohio Department of Agriculture.

Counties	No. townships reported	What is average wage paid to farm hands			
		By day with board	By day without board	By month with board	By month without board
Putnam	9	$1.36	$1.72	$21.65	$28.20
Richland	15	1.45	1.87	22.00	31.45
Ross	11	.96	1.23	19.50	27.32
Sandusky	9	1.39	1.80	25.70	37.00
Scioto	15	1.00	1.30	20.14	29.20
Seneca	12	1.46	1.39	24.25	34.30
Shelby	9	1.33	1.72	22.12	29.17
Stark	14	1.27	1.77	23.43	36.22
Summit	16	1.50	1.81	22.81	34.09
Trumbull	19	1.24	1.68	23.63	33.06
Tuscarawas	17	1.11	1.49	22.45	31.30
Union	14	1.30	1.66	21.61	29.73
Van Wert	8	1.33	1.64	22.50	31.57
Vinton	10	.88	1.29	20.66	29.80
Warren	9	1.11	1.58	21.50	29.50
Washington	19	.96	1.36	18.62	25.79

*Counties with townships having more than one reporter

In the spring of 1913 inquiries regarding the various rates of wages paid for labor of different classes were sent to the mayors of Ohio municipalities having a population between 2,500 and 10,000. Table II gives the results of these inquiries.

TABLE II. Showing rates of wage and days worked per year for different classes of workmen in 34 Ohio municipalities with an average population of 5,831.

Munici-pality number	Popula-tion	Common laborer: Wage per day Min.	Common laborer: Wage per day Max.	Common laborer: Hours worked per day	Common laborer: Days worked per year	Common laborer with team: Wage per day Min.	Common laborer with team: Wage per day Max.	Common laborer with team: Hours worked per day	Common laborer with team: Days worked per year	Carpenter: Wage per day Min.	Carpenter: Wage per day Max.	Carpenter: Hours worked per day	Carpenter: Days worked per yr.	Stone mason: Wage per day Min.	Stone mason: Wage per day Max.	Stone mason: Hours worked per day	Stone mason: Days worked per yr.
1	6,795	$1.75	$2.00	10	190	$5.00	$6.00	10	175	$2.00	$3.50	10	225	$3.50	$4.50	10	185
2	5,209	2.00	2.50	10	200	5.00	6.00	10	200	2.50	3.50	10	250	4.50	5.00	9	140
3	5,222	1.75	2.00	10	230	3.50	4.00	10	230	3.50	....	10	200	....	....	..	...
4	6,621	1.50	2.00	10	300	4.00	4.50	10	220	2.50	3.50	10	250	4.00	5.00	10	200
5	9,603	1.75	....	9	190	5.00	....	9	140	3.50	....	8	240	5.00		8	100
6	3,028	2.00	5.00	8	300	4.50	....	8	300	3.00	3.00	8	260	5.00	5.00	8	156
7	4,665	1.75	2.25	10	260	3.50	4.00	10	260	3.00	....	10	230	5.00	....	10	200
8	3,187	1.75	2.50	10	250	3.50	4.00	10	250	2.50	3.00	9	280	4.00	5.00	9	250
9	9,597	1.75	2.00	10	230	2.00	2.00	10	230	3.00	3.50	8	230	5.00	5.50	8	230
10	7,214	....	2.00	10	250	....	4.50	10	250	2.75	3.20	10	250	3.50	6.00	10	250
11	5,560	1.25	1.50	9	260	3.00	3.50	9	260	2.50	2.75	9	208	3.50	4.00	9	156
12	3,736	1.35	2.00	10	300	5.00	5.50	9	300	4.00	....	8	300	....	4.00	8	300
13	6,237	1.75	2.50	10	200	3.50	4.00	10	200	1.75	3.50	10	250	3.50	4.00	10	160
14	4,488	....	1.75	10	203	....	4.50	10	222	....	....	..	...	....	....	.	...
15	7,185	1.75	2.00	10	210	4.00	4.00	10	200	3.00	3.00	10	200	4.00	4.00	10	200
16	4,850	1.50	2.00	10	260	4.00	4.50	10	260	2.50	3.50	10	260	3.50	4.00	10	260
17	9,133	1.50	2.00	10	208	4.50	5.00	9	208	3.20	3.40	8	208	....	5.00	8	208
18	2,734	1.50	2.00	10	240	4.00	5.00	10	240	2.50	3.00	10	275	3.00	5.00	10	275
19	4,271	1.50	2.00	10	270	3.50	4.00	10	200	2.25	3.25	10	300	2.25	3.25	10	250
20	2,759	1.75	2.25	10	250	4.00	4.50	10	180	2.50	3.00	10	200	5.00	6.00	10	100
21	9,087	1.50	2.00	10	290	3.50	5.00	10	270	2.25	3.50	8	270	....	5.00	8	150
22	8,542	1.60	2.00	10	250	....	4.50	10	200	2.50	3.50	10	150	3.00	4.50	10	150
23	8,361	1.75	2.00	9	300	....	4.95	9	250	3.25	3.25	8	250	....	5.20	8	225
24	4,365	1.50	2.00	10	200	5.00	5.50	10	200	3.00	3.50	10	225	4.00	4.50	8	200
25	4,023	1.25	1.50	9	200	4.50	....	9	200	2.50	3.50	8	200	2.50	3.50	8	175
26	8,943	1.75	2.25	9	300	4.50	5.00	9	200	3.25	3.40	9	200	4.80	4.80	8	200
27	4,903	1.75	2.50	10	300	5.00	....	10	250	2.50	3.00	10	250	4.00	5.00	9	200
28	6,607	1.75	2.00	10	200	3.75	4.50	10	200	2.50	3.00	10	250	4.00	5.50	10	200
29	5,732	1.35	1.75	10	280	3.25	3.75	10	260	1.75	2.25	10	256	3.50	4.00	10	220
30	6,122	1.75	2.00	10	230	3.50	4.00	10	156	2.50	3.00	10	156	....	5.00	10	156
31	4,751	1.50	2.00	10	300	4.50	5.00	9	300	2.50	3.50	9	300	4.00	4.00	9	150
32	7,157	1.50	2.50	9	300	3.50	5.00	9	300	2.50	4.00	9	300	2.50	5.00	10	156
33	3,073	1.50	2.00	10	250	4.00	4.50	10	212	2.25	3.00	9	225	....	....	..	...
34	4,491	1.50	2.25	10	200	3.50	4.00	10	200	3.00	4.50	10	225	4.00	5.00	10	175
Total....	198,251	$51.80	$71.00	332	8,391	$120.00	$135.20	329	7,723	$88.70	$95.50	308	7,873	$100.55	$136.25	285	5,977
Average.	5,831	1.62	2.15	9.76	246.79	4.00	4.51	9.68	227.15	2.69	3.29	9.33	238.58	3.87	4.70	9.19	192.81
Rate per hour......		.166	.22	......	....	.413	.466	......	....	.29	.353	......	....	.405	.511	......	......
Av. daily wage		$1.89				$4.25				$2.97				$4.31			
Av. rate per hour...		.194				.439				.318				.469			

TABLE II.—Continued. Showing rates of wage and days worked per year for different classes of workmen in 34 Ohio municipalities with an average population of 5,831.

Municipality number	Population	Brick mason: Wage per day, Min.	Brick mason: Wage per day, Max.	Brick mason: Hours worked per day	Brick mason: Days worked per year	Painter: Wage per day, Min.	Painter: Wage per day, Max.	Painter: Hours worked per day	Painter: Days worked per year	Plumber: Wage per day, Min.	Plumber: Wage per day, Max.	Plumber: Hours worked per day	Plumber: Days worked per year
1	6,795	$5.00	$5.00	10	180	$2.00	$3.50	10	200	$5.00	$5.00	10	225
2	5,209	4.90	5.40	9	200	2.50	3.00	10	200	4.00	5.00	10	250
3	5,222	....	....	..	...	....	....	..	...	....	....	..	...
4	6,621	4.00	5.00	10	200	2.50	3.20	10	220	2.70	3.50	9	300
5	9,603	5.00	....	8	140	2.75	....	8	100	3.50	....	9	240
6	3,028	5.00	5.00	8	182	3.20	3.20	8	208	4.00	4.00	8	234
7	4,665	5.00	....	10	200	3.00	....	10	230	5.00	....	10	260
8	3,187	4 00	5.00	9	250	3.00	3.50	10	280	3.50	5.00	10	300
9	9,597	5.00	5.50	8	230	3.00	3.50	8	230	4.00	6.00	10	300
10	7,214	3.50	6.00	10	250	2.50	3 00	10	250	4.50	4.50	10	250
11	5,560	5.00	6.00	9	156	2.00	3.00	9	156	....	....	..	...
12	3,736	....	5.20	8	300	....	3.60	8	300	....	4.50	8	300
13	6,237	2.70	5.60	9	200	2.00	3.00	10	180	2.50	5.00	10	250
14	4,488	....	....	..	...	....	....	..	...	....	....	..	...
15	7,186	4.00	4.00	10	200	3.00	3.00	10	200	4.00	4 00	10	200
16	4,850	5.00	6.00	10	260	2.00	2.50	10	260	3.00	3.50	10	260
17	9,133	....	4.80	8	208	....	3.60	8	208	....	4.00	8	234
18	2,734	3.00	5.00	10	275	2.50	3.00	10	250	2.50	3.50	10	250
19	4,271	3.50	6.00	10	200	2.25	3.00	10	275	3.50	5.00	10	300
20	2,759	5.00	6.00	10	130	2.00	3.00	10	120	3.50	4.00	10	250
21	9,087	....	6.00	8	150	2.50	3.50	9	180	2.00	4.00	9	270
22	8,542	4.50	5.60	10	150	2.50	3.50	10	150	5.00	6.00	10	250
23	8,361	....	5.20	8	225	3.00	3.00	9	225	....	4.50	9	250
24	4,365	4.00	4.50	8	200	2.00	2.50	8	225	3.00	5.00	9	300
25	4,023	3 50	4.50	8	175	2.00	3.00	9	125	4.50	5.50	8	125
26	8,943	5.00	5.00	8	200	3.00	3.15	9	200	3.60	3.60	8	250
27	4,903	4.00	5 00	9	200	3.00	3.50	10	200	4.50	....	10	300
28	6,607	6.00	6.50	10	200	2.50	3.00	10	225	3.50	4.00	10	275
29	5,732	4.00	4.80	8	230	2.00	2.25	10	250	3.00	3.50	10	300
30	6,122	....	5.00	10	156	2.00	2.50	10	156	4.00	5 00	10	234
31	4,751	4.50	4.50	8	150	2.50	3.00	9	150	3.00	3 50	9	300
32	7,157	2.50	6.00	10	156	2.50	3.50	9	260	3.50	4.00	10	300
33	3,073	4.00	5.00	8	212	2.25	3.00	10	225	2.50	3.50	10	237
34	4,491	4.00	5.00	10	175	2.00	3.00	10	240	2.50	4.00	10	275
Total....	198,251	$115.60	$158.10	289	6,340	$73.95	$93.00	301	6,678	$99.80	$122 60	294	8 069
Average.	5,831	4.28	5.27	9.03	198.12	2.46	3.10	9.41	208.69	3.56	4.38	9.48	260 29
Rate per hour......		.474	.584	......	....	.261	.329	......	....	.376	.462	......	....
Av. daily wage.....		$4.80				$2.78				$3.97			
Av. rate per hour...		.532				.295				.419			

CLASSIFICATION OF THE RECORDS

In getting together the individual records of fields of corn and combining them, they naturally fall into certain groups or classes. One of the first classifications necessary to make is based on the general method by which the corn crop is harvested. The following outline shows the general methods adopted for this classification, and Tables III, IV, V and VI respectively, give the data by counties classified in that manner.

Grain harvested:—All the hours of labor reported. May include any combination of the following special methods of harvesting, with their attendant operations:

- Cut by hand
- Cut by machine
- Husked by hand—either from shock or standing stalk
- Husked by machine
- Fodder shredded.

Hogged off:—

Siloed:—Cut in the field either by hand or by machine.

Contract labor additional:—A part or all of the labor, especially in harvesting, done at a contract price and the hours of such labor not reported.

TABLE III. Labor required when grain is harvested.

County	Number of fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre	
			Man	Horse	Man	Horse
Allen	10	112.97	6,493.25	6,910.50	57.48	61.17
Ashtabula	1	4.21	273.44	267.22	64.95	63.47
Athens	1	2.83	213.75	160.00	75.53	56.54
Belmont	3	31.53	2,673.77	1,984.89	84.80	62.95
Coshocton	7	88.21	7,037.50	6,845.50	79.78	77.60
Crawford	11	115.27	5,667.25	5,546.50	49.16	48.12
Geauga	6	23.89	1,524.75	1,442.75	63.82	60.39
Greene	2	7.47	307.50	304.75	41.16	40.80
Hardin	7	76.37	3,103.32	4,151.24	40.64	54.36
Harrison	2	13.61	971.00	759.50	71.34	55.80
Holmes	12	133.28	7,633.49	9,065.33	57.27	68.02
Huron	8	96.10	4,755.19	5,966.65	49.48	62.09
Licking	3	29.56	1,437.25	1,616.00	48.62	54.67
Lorain	2	7.37	632.50	646.50	85.82	87.72
Madison	4	122.81	4,686.50	5,261.25	38.16	42.84
Meigs	6	8.85	863.75	710.75	97.60	80.31
Pickaway	6	202.34	8,380.81	8,923.76	41.42	44.10
Preble	11	252.53	7,406.50	13,989.00	29.33	55.40
Putnam	2	20.66	1,058.00	1,029.00	51.21	49.81
Seneca	1	12.01	660.75	514.25	55.02	42.82
Warren	3	39.33	1,723.75	1,584.50	43.83	40.29
Total	108	1,401.20	67,504.02	77,679.84	.....	.....
Average	...	12.97	....	......	48.18	55.44

TABLE IV. Labor required when corn is hogged off.

County	Number of fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre	
			Man	Horse	Man	Horse
Crawford.......	2	18.07	416.75	732.00	23.06	40.51
Hardin.........	2	10 92	170 75	342.75	15.64	31.39
Holmes.........	4	22.89	693.65	1,137 52	30.30	49 70
Madison	3	20.67	577.50	962.25	27.94	46.55
Pickaway......	2	25.06	537.34	1,010 20	21.44	40 31
Preble	3	13.87	277.00	515.00	19.97	37.13
Warren.......	1	6.02	74.50	143.00	12.38	23.75
Total	17	117.50	2,747.49	4,842.72	.....	...
Average	..	6.91	....	....	23.38	41.21

TABLE V. Labor required when corn is siloed.

County	Number of fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre	
			Man	Horse	Man	Horse
Allen...........	2	23.47	1,735.00	2,056.25	73.92	87.61
Ashtabula.....	2	10 59	580.86	647.69	54.85	61.16
Belmont........	1	7.72	433.75	568.75	56.18	73.67
Geauga.........	4	29.06	1,769.00	2,089.50	60.87	71.90
Hardin	2	15.75	726.18	1,048.26	46.11	66.56
Harrison.......	1	10.70	433.25	431.25	40.49	40.30
Seneca...... ..	4	18.49	946.25	1,091.50	51.18	59.03
Total..........	16	115.78	6,624.29	7,933.20	....	.....
Average.......	..	7.24	....	....	57.21	68.52

TABLE VI. Labor required when there is contract labor additional.

County	Number fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre		Total value of contract labor	Value of contract labor per acre
			Man	Horse	Man	Horse		
Adams.....	4	66 71	2,850.75	3,557.25	42.73	53.32	$113.89	$1.71
Allen.......	2	51 59	3,351.75	3,770.25	64.97	73.08	42 87	.83
Athens.....	5	10 04	656.00	774.25	65.34	77 13	21 91	2 18
Belmont....	1	10.28	635.25	597.50	61.79	58.12	16 75	1 63
Clinton	1	32.00	1,118.50	2,002.00	34.95	62 56	12.60	.39
Geauga....	1	6 52	318.50	330.75	48.86	50 74	4 50	69
Greene. ...	2	48 37	1,421.25	1,852 75	29.38	38 30	111.48	2.30
Hardin....	3	58.19	2,482.00	3,458.50	42.65	59.43	48.18	83
Holmes....	2	34 28	1 554.57	2,734 96	45 35	79 78	44.10	1 29
Huron......	3	62.00	3,607.21	3,904.57	58.18	62.98	38 76	63
Madison. ..	8	199 96	7 887.25	9,692.25	39.44	48 47	297 70	1.49
Pickaway.	2	76.57	3,060.39	3,923.86	39 97	51.25	81.96	1.07
Preble.	1	17.71	357.50	817.00	20.19	46 13	34.40	1 94
Seneca	1	13.61	938.75	723.50	68.98	53.16	4.29	.31
Total......	36	687.83	30,239.67	38,139.39	.....	.....	$873.30	..
Average...	..	19.11	....	....	43.96	55.45	... ..	$1.27

TABLE VII. Recapitulation of Tables III, IV, V and VI.

Table	Number of fields	Total acreage of fields	Average size of fields	Total hours of labor		Hours of labor per acre		Horse hours used per hour of man labor
				Man	Horse	Man	Horse	
Table III..	108	1,401.20	12.97	67,504.02	77,679.84	48.18	55.44	1.15
Table IV..	17	117.50	6.91	2,747.49	4,842.72	23.38	41.21	1.76
Table V...	16	115.78	7.24	6,624.29	7,933.20	57.21	68.52	1.20
Table VI*.	36	687.83	19.11	30,239.67	38,139.39	43.96	55.45	1.26

*$1.27 per acre additional for contract labor.

Fig. 3. Some methods of harvesting corn.

While one would hardly be justified in combining the totals of these various methods and deducing therefrom an average labor cost of producing the corn crop, it is a significant fact that the average of all of these fields, regardless of the method of harvesting, is 46.12 man hours and 55.37 horse hours per acre, with 1.20 horse

hours per hour of man labor, which averages are not materially different from those shown in Table III. However, the data for plotting the charts referred to in this Bulletin, Figures 4, 5, 7, 8, 9, 10 and 11, were secured from Table III.

If the rates of man and horse labor (16c and 8c respectively), previously mentioned, be used in connection with the average hours per acre (48.18 man hours and 55.44 horse hours) as shown in Table III, the average cost of labor only, on the 108 fields of corn is found to be $12.14 per acre.

From Table VIII the labor cost of producing an acre of corn may be determined when varying rates of man and horse labor are used in connection with the average hours shown in Table III. This cost per acre, including both man and horse labor at any given rate for each, is determined by finding the rate of man labor on the left, and following that rate across horizontally until we reach the column which has the selected horse rate at the top. For example, if the rates of 16c per hour for man and 8c per hour for horse labor are used, the rate of 16c is found on the left, and following this line across until the column headed 8c is reached, it is found that the cost of man and horse labor combined is $12.14.

TABLE VIII: Showing total labor cost per acre at varying prices per hour for man and horse labor: based on 48.18 man hours and 55.44 horse hours per acre, as per Table III.

Man hour prices	Horse hour prices											
	5c	6c	7c	8c	9c	10c	11c	12c	13c	14c	15c	16c
10c	$7.59	$8.14	$8.70	$9.25	$9.81	$10.36	$10.92	$11.47	$12.03	$12.58	$13.13	$13.69
12c	8.55	9.11	9.66	10.22	10.77	11.33	11.88	12.43	12.99	13.54	14.10	14.65
14c	9.52	10.07	10.63	11.18	11.73	12.29	12.84	13.40	13.95	14.51	15.06	15.62
16c	10.48	11.04	11.59	12.14	12.70	13.25	13.81	14.36	14.92	15.47	16.02	16.58
18c	11.44	12.00	12.55	13.11	13.66	14.22	14.77	15.33	15.88	16.43	16.99	17.54
20c	12.41	12.96	13.52	14.07	14.63	15.18	15.73	16.29	16.84	17.40	17.95	18.51
22c	13.37	13.93	14.48	15.03	15.59	16.14	16.70	17.25	17.81	18.36	18.92	19.47
24c	14.34	14.89	15.44	16.00	16.55	17.11	17.66	18.22	18.77	19.32	19.88	20.43
26c	15.30	15.85	16.41	16.96	17.52	18.07	18.63	19.18	19.73	20.29	20.84	21.40
28c	16.26	16.82	17.37	17.93	18.48	19.03	19.59	20.14	20.70	21.25	21.81	22.36
30c	17.23	17.78	18.33	18.89	19.44	20.00	20.55	21.11	21.66	22.22	22.77	23.32
32c	18.19	18.74	19.30	19.85	20.41	20.96	21.52	22.07	22.62	23.18	23.73	24.29
34c	19.15	19.71	20.26	20.82	21.37	21.93	22.48	23.03	23.59	24.14	24.70	25.25
36c	20.12	20.67	21.23	21.78	22.33	22.89	23.44	24.00	24.55	25.11	25.66	26.22
38c	21.08	21.63	22.19	22.74	23.30	23.85	24.41	24.96	25.52	26.07	26.62	27.18
40c	22.04	22.60	23.15	23.71	24.26	24.82	25.37	25.92	26.48	27.03	27.59	28.14
42c	23.01	23.56	24.12	24.67	25.23	25.78	26.33	26.89	27.44	28.00	28.55	29.11
44c	23.97	24.53	25.08	25.63	26.19	26.74	27.30	27.85	28.41	28.96	29.52	30.07
46c	24.93	25.49	26.04	26.60	27.15	27.71	28.26	28.82	29.37	29.92	30.48	31.03
48c	25.90	26.45	27.01	27.56	28.12	28.67	29.22	29.78	30.33	30.89	31.44	32.00
50c	26.86	27.42	27.97	28.53	29.08	29.63	30.19	30.74	31.30	31.85	32.41	32.96
52c	27.83	28.38	28.93	29.49	30.04	30.60	31.15	31.71	32.26	32.82	33.37	33.92
54c	28.79	29.34	29.90	30.45	31.01	31.56	32.12	32.67	33.22	33.78	34.33	34.89
56c	29.75	30.31	30.86	31.42	31.97	32.52	33.08	33.63	34.19	34.74	35.30	35.85
58c	30.72	31.27	31.83	32.38	32.93	33.49	34.04	34.60	35.15	35.71	36.26	36.81
60c	31.68	32.23	32.79	33.34	33.90	34.45	35.01	35.56	36.12	36.67	37.22	37.78

Table IX will assist in calculating the number of bushels per acre of corn, at varying prices, which are necessary to pay the labor cost of production. The price per bushel is given at the top of the table, and the labor cost, as taken from Table VIII, is given at the left. The method of finding the number of bushels per acre is the same as was explained for finding the combined cost of man and horse labor. For example, if the total labor cost is $12.14, and the price per bushel is 40c, we find the $12.14 on the left and follow this across horizontally until we reach the column headed 40c where we find that the number of bushels per acre, at 40c per bushel, required to pay for that labor cost of production is 30.35 bu.

TABLE IX: Showing the number of bushels of corn per acre necessary to pay the labor cost of production at various costs and prices per bushel, no credit being allowed for value of stover.

Value of labor per acre	Price of corn per bushel										
	30c	35c	40c	45c	50c	55c	60c	65c	70c	75c	80c
$7.59	25.30	21.69	18.98	16.87	15.18	13.80	12,65	11.68	10.84	10.12	9.49
9.11	30.37	26.03	22.78	20.24	18.22	16.56	15.18	14.02	13.01	12.15	11.39
10.63	35.43	30.37	26.58	23.62	21.26	19.32	17.72	16.35	15.19	14.17	13.29
12.14	40.47	34.69	30.35	26.98	24.28	22.07	20.23	18.68	17.34	16.19	15.18
13.66	[illegible] 53	39.03	34.15	30.36	27.32	24.84	22.77	21.02	19.51	18.21	17.08
15.18	50.60	43.37	37.95	33.73	30.36	27.60	25.30	23.35	21.69	20.24	18.98
16.70	55.67	47.71	41.75	37.11	33.40	30.36	27.83	25.69	23.86	22.27	20.88
18.22	60.73	52.06	45.55	40.49	36.44	33.13	30.37	28.03	26.03	24.29	22.78
19.73	65.77	56.37	49.32	43.84	39.46	35.87	32.88	30.35	28.19	26.31	24.66
21.25	70.83	60.71	53.12	47.22	42.50	38.64	35.42	32.69	30.36	28.33	26.56
22.77	75.90	65.06	56.92	50.60	45.54	41.40	37.95	35.03	32.53	30.36	28.46
24.29	80.97	69.40	60.72	53.97	48.58	44.16	40.48	37.37	34.70	32.39	30.36

During the period 1905 to 1911, inclusive, the average annual area of corn in Ohio was 3,005,981 acres; the average annual total production was 112,773,950 bushels, or an average yield per acre of 37.52 bushels.* From the yearbooks of the United States Department of Agriculture for this same period the mean farm price of corn in Ohio on December first was found to be 51c. At this price per bushel for corn it would require 23.8 bushels to pay the labor cost of production previously mentioned—$12.14. This leaves a difference of 13.72 bushels, or, at 51c per bushel, $7.00, with which to pay for the fertilizer, seed, land rental, machinery cost, etc. When these expenses are paid there certainly cannot be much left as profits.

Referring to the contract labor table (Table VI) it will be noted that the hours of labor per acre actually reported are less than those shown in Table III, and that, at the assumed rates, the combined

*From the reports of the Ohio State Board of Agriculture.

labor cost exclusive of contract labor is but $11.47. From the same table it will be noted that on these fields there is an average of $1.27 per acre to be added for work done at a contract price, for which the hours of labor are not reported. This, added to the $11.47, brings the total labor cost for that class of fields up to $12.74 per acre.

TABLE X: Showing data in Table III grouped according to sections.

County	Number of fields reported	Total acreage of fields	Total hours of labor		Hours of labor per acre	
			Man	Horse	Man	Horse
Southeast section:						
Athens	1	2.83	213.75	160.00	75.53	56.54
Belmont	3	31.53	2,673.77	1,984.89	84.80	62.95
Coshocton	7	88.21	7,037.50	6,845.50	79.78	77.60
Harrison	2	13.61	971.00	759.50	71.34	55.80
Holmes	12	133.28	7,633.49	9,065.33	57.27	68.02
Meigs	6	8.85	863.75	710.75	97.60	80.31
Total	31	278.31	19,393.26	19,525.97	.....	....
Average	..	8.98	....	....	69.68	70.16
Northeast section:						
Ashtabula	1	4.21	273.44	267.22	64.95	63.47
Geauga	6	23.89	1,524.75	1,442.75	63.82	60.39
Lorain	2	7.37	632.50	646.50	85.82	87.72
Total	9	35.47	2,430.69	2,356.47	.....	.....
Average		3.94	....	....	68.53	66.44
Northwest section:						
Allen	10	112.97	6,493.25	6,910.50	57.48	61.17
Crawford	11	115.27	5,667.25	5,546.50	49.16	48.12
Hardin	7	76.37	3,103.32	4,151.24	40.64	54.36
Huron	8	96.10	4,755.19	5,966.65	49.48	62.09
Licking	3	29.56	1,437.25	1,616.00	48.62	54.67
Putnam	2	20.66	1,058.00	1,029.00	51.21	49.81
Seneca	1	12.01	660.75	514.25	55.02	42.82
Total	42	462.94	23,175.01	25,734.14	.....	.....
Average	..	11.02	....	....	50.06	55.59
Southwest section:						
Greene	2	7.47	307.50	304.75	41.16	40.80
Madison	4	122.81	4,686.50	5,261.25	38.16	42.84
Pickaway	6	202.34	8,380.81	8,923.76	41.42	44.10
Preble	11	252.53	7,406.50	13,989.00	29.33	55.40
Warren	3	39.33	1,723.75	1,584.50	43.83	40.29
Total	26	624.48	22,505.06	30,063.26	.....	.....
Average	..	24.02	....	....	36.04	48.14

REGIONAL DISTRIBUTION

For reasons shown later these records group themselves into four sections with reference to their distribution over the State, which sections may be called the Southeast, Northeast, Northwest and Southwest. In these records the Southeast section includes the counties of Adams, Athens, Belmont, Coshocton, Harrison, Holmes

and Meigs. The Northeast is represented by Ashtabula, Geauga and Lorain. The Northwest section includes Allen, Crawford, Hardin, Huron, Licking, Putnam and Seneca, while the Southwest includes Clinton, Green, Madison, Pickaway, Preble and Warren counties. Table X groups the data of Table III according to sections as defined.

When the average hours per acre shown by Table X are reduced to dollars and cents (at 16c per hour for man and 8c per hour for horse labor) it is found that in the Southwest section the labor of producing the corn crop amounts to $9.62 per acre, or $2.52 per acre less than the state average of $12.14. On the other hand, in the Northeast section the labor amounts to $16.28 per acre, and in the Southeast section it is $16.76 per acre, considerably above the average of the state, whereas the labor in the Northwest section is costing an average of $12.46 per acre, or only 32 cents per acre more than the average of the state.

Figures 4 and 5 show graphically the percentage comparison of the four groups outlined in Table X, with the state average of the 108 fields so grouped. Table XI gives in tabular form the same data as are shown in Figures 4 and 5.

TABLE XI. Showing relative amount of labor expended per acre in growing corn in the various sections of Ohio as compared with the State average, and the percentage variation from the State average in each section.

Partial items	Southeast section 31 fields, av. 8.98 A.		Northeast section 9 fields, av. 3.94 A.		Northwest section 42 fields, av. 11.02 A.		Southwest section 26 fields, av. 24.02 A.		State average 108 fields, av. 12.97 acres
	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre
Man labor									
Preparation of seed bed	9.21	16	11.86	50	8.12	3	6.97	−12	7.92
Planting	2.92	64	2.17	22	1.85	4	1.21	−32	1.78
Cultivating	15 52	57	11.53	17	9.13	−8	7.00	−29	9.89
Harvesting	26.65	27	33.37	59	22.95	9	16.29	−22	20.98
Total*	69.68	45	68.53	42	50.06	4	36.04	−25	48.18
Horse labor									
Preparation of seed bed	25.25	23	27.03	31	19.44	−6	18.88	−8	20.58
Planting	2.28	13	2.35	16	2.12	5	1.80	−11	2.02
Cultivating	12.28	−7	11.64	−12	13.00	−1	13.75	4	13.16
Harvesting	14.28	15	14.72	19	13.52	9	10.61	−14	12.40
Total*	70.16	27	66.44	20	55.59	3	48.14	−13	55.44

*As explained on page 90 several of the miscellaneous partial items have not been shown. The totals, however, include all partial items.

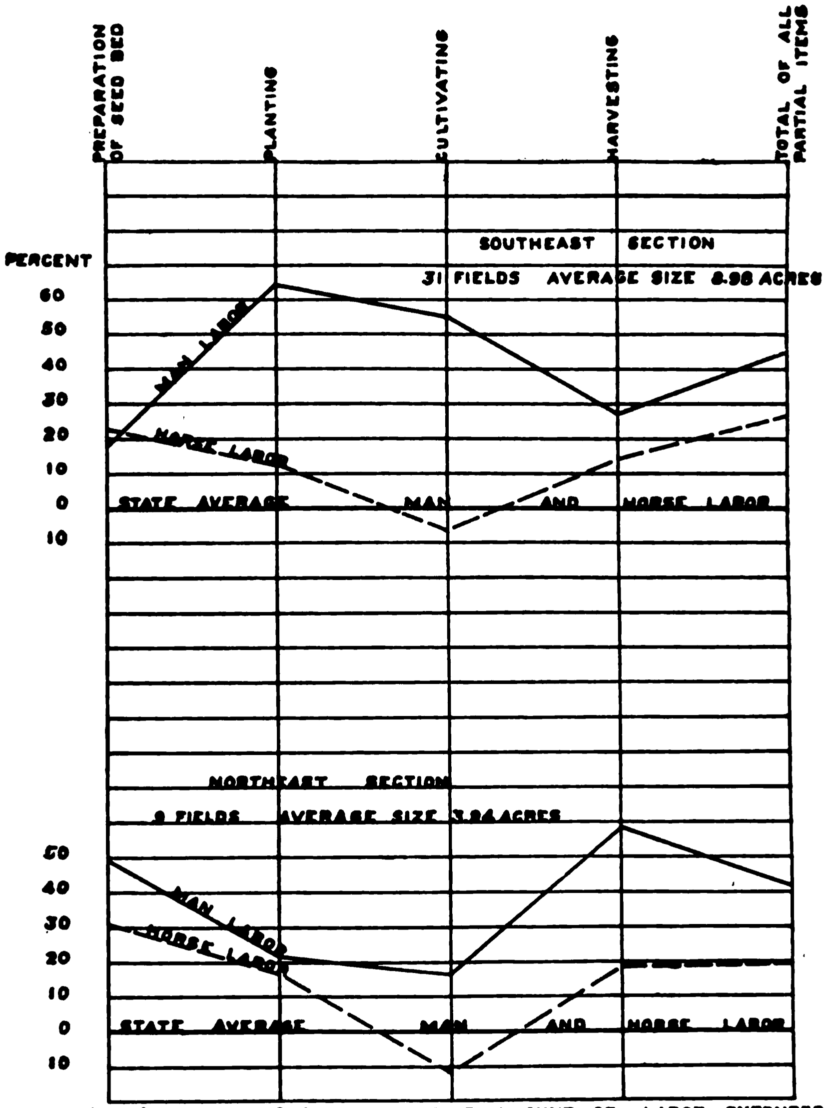

FIG. 4 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN THE SOUTHEAST AND NORTHEAST SECTIONS OF OHIO AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS

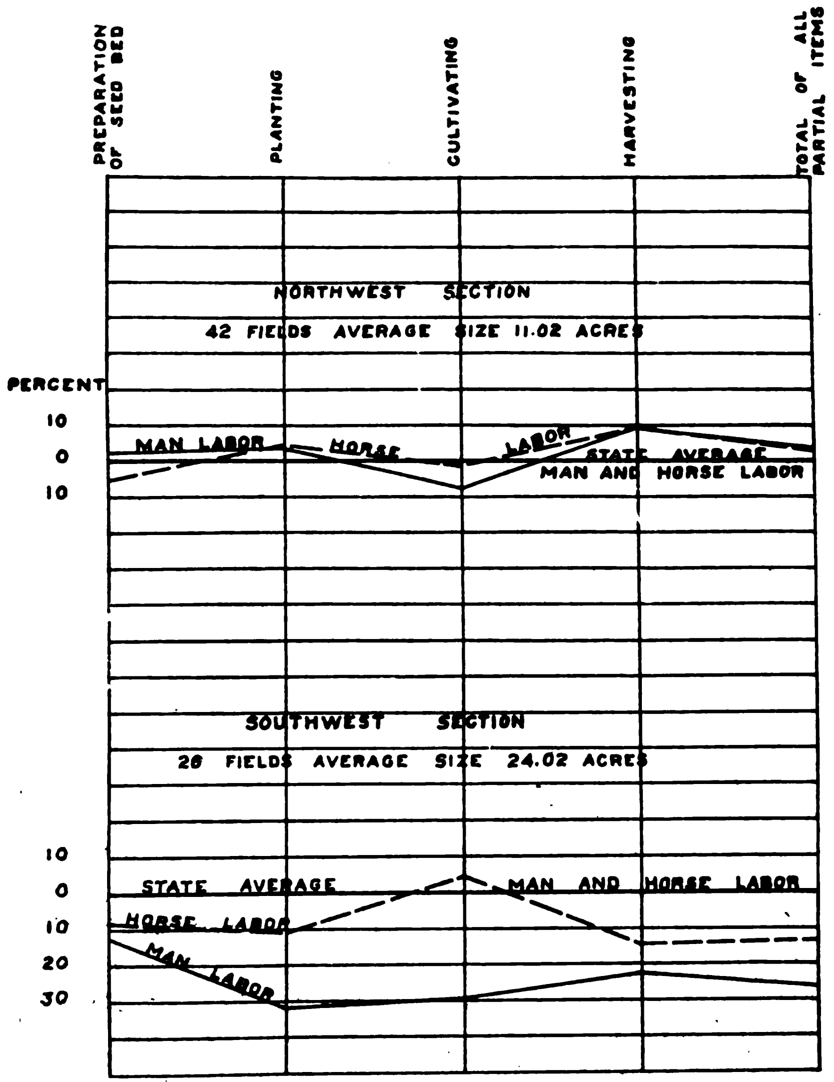

FIG. 5 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN THE NORTHWEST AND SOUTHWEST SECTIONS OF OHIO AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS

In these and succeeding charts of a similar nature the straight horizontal line is considered as the state average for both man and horse hours. Each partial item is then plotted as so many percent above or below the state average. For example, in Figure 4 the state average man hours for preparation of the seed bed is 7.92 hours. The average for the fields in the Southeast section is 9.21 hours, which is 16.3 percent more than the state average. Therefore, in Figure 4 the man hours for preparation of seed bed are plotted at 16 percent above the straight line which, as stated, represents the state average. Likewise the state average horse hours for the preparation of the seed bed is 20.58 hours. In the Southeast section 25.25 horse hours are required for this item, which is 22.69 percent more than the state average. Accordingly, in Figure 4 the horse hours for preparation of seed bed are plotted as 23 percent above the same straight line, since it represents the state average of horse hours as well as of man hours.

Tables X and XI or Figures 4 and 5 show that there is a gradual decrease in both man and horse hours per acre, as well as in the total labor cost per acre, in passing from the Southeast through the Northeast and Northwest to the Southwest section. There are a number of factors by which this decrease can be explained. In the Southeast section the topography is perhaps the greatest limiting factor. In this section the country is rough and broken, and while the average size of the farms is above the average of the State, yet the topography necessitates very irregular and not infrequently very small cultivated fields.

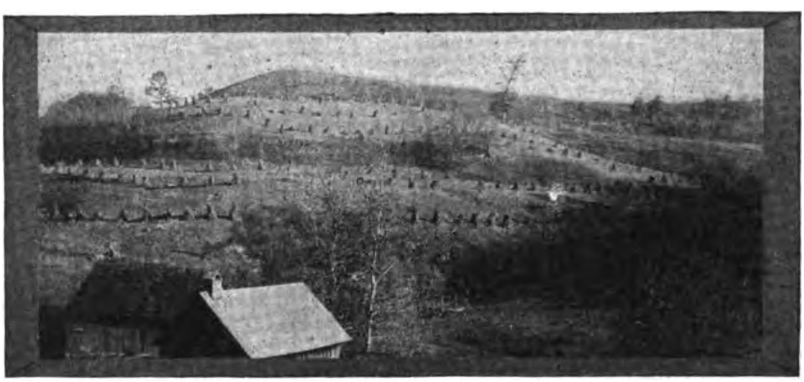

Fig. 6. Growing corn on the hillsides of Southeastern Ohio.

In the Northeast section the origin of the early settlers is probably an important factor, influencing as it does the type of farming, the size of farms and size of tools used. From a

topographic standpoint there is scarcely any reason why the farmers in this section should not use larger tools, utilizing more horses per man, and thus, in a measure, reducing the labor cost of production. However, the early settlers of this region came from New England, a rugged and broken country, where 70 to 80 acres were considered to be a large farm. They were thus familiar with the use of smaller tools and consequently adopted them in their work in Ohio. In this section also there is comparatively little tile drainage, the lack of which doubtless makes the soils heavier and harder to work, so that the farmers cannot use their labor so effectively. In the Northwest and especially the Southwest sections the influence of the more level country, better drainage, the use of larger tools and of more horses per workman is apparent.

SIZE OF FIELD

However, the difference in labor cost cannot all be explained on the basis of regional distribution. The size of fields must also be taken into consideration. A great deal has been said and written regarding the size of farms. Many who are not engaged in farming, and even some farmers, believe that smaller farms better tilled would bring greater profits than the larger farms. There may be room for improvement in the cultural methods on the larger farms, but as Warren has shown in Bulletin 295, of the Cornell University Experiment Station, the small farms have many disadvantages. He shows that while the receipts per acre on small farms are more than on the larger ones, the single item of labor on the small farm is so great that it more than offsets the difference in receipts. This is true not only for man labor, but also for horse labor. While only a limited amount of farm management survey work has been done in this state, so far as we have gone the same conditions are found in the areas that have been surveyed. As a general rule small farms must mean smaller fields, and accordingly we would expect the labor cost to increase as the size of the field decreases. This we do find, as is shown by Table XII and Figures 7, 8 and 9, the data for which were secured by regrouping Table III. These tables show the average percentage variation due to size of fields as compared with the average of all the 108 fields. While the man and horse labor may not both decrease as the size of the field increases, yet the combined cost, expressed in dollars and cents, does constantly decrease as the size of the field increases. In Table XIII will be found a probable explanation as to why the man or horse hours do not decrease uniformly as the size of fields increase.

TABLE XII. Showing relative amount of labor expended per acre in growing corn on various sized fields, and the percentage variation from the State average for each group of fields.

Partial items	Group .01—2.49 A. 15 fields, av. 1.65 A.		Group 2.5—4.99 A. 12 fields, av. 3.73 A.		Group 5—9.99 A. 19 fields, av. 7.50 A.		Group 10—14.99 A. 33 fields, av. 12.22 A.		Group 15—19.99 A. 8 fields, av. 17.72 acres		Group 20—24.99 A. 10 fields, av. 21.52 acres		Group 25 A. and over, 11 fields, av. 39 acres		State average 108 fields, av. 12.97 A.
	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre	Variation Percent	Hours per acre
Man labor															
Preparation of seed bed	12.89	63	9.26	17	10.06	27	8.40	6	7.37	—7	6.23	—21	7.38	—7	7.92
Planting	3.94	121	1.49	—16	2.29	29	2.33	31	1.86	4	1.13	—36	1.32	—26	1.78
Cultivating	22.43	127	11.52	16	15.57	57	10.69	8	9.20	—7	8.31	—16	7.40	—25	9.89
Harvesting	31.69	51	28.22	34	26.19	25	24.64	17	22.89	9	15.14	—28	16.81	—20	20.98
Total*	84.79	76	59.53	24	62.03	29	56.63	18	50.76	5	36.20	—25	37.14	—23	48.18
Horse labor															
Preparation of seed bed	26.69	30	23.55	14	22.58	10	21.66	5	21.00	2	18.28	—11	19.30	—6	20.58
Planting	3.28	62	2.40	19	2.47	22	2.05	2	2.14	6	1.63	—19	1.88	—7	2.02
Cultivating	12.92	—2	12.36	—6	13.03	—1	12.49	—5	11.77	—11	14.91	13	13.54	3	13.16
Harvesting	12.91	4	14.82	20	12.19	—2	13.43	8	16.04	29	10.46	—16	11.04	—11	12.40
Total*	69.21	25	63.31	14	57.72	4	60.53	9	59.84	8	50.07	—10	49.81	—10	55.44

*See foot note to Table XI.

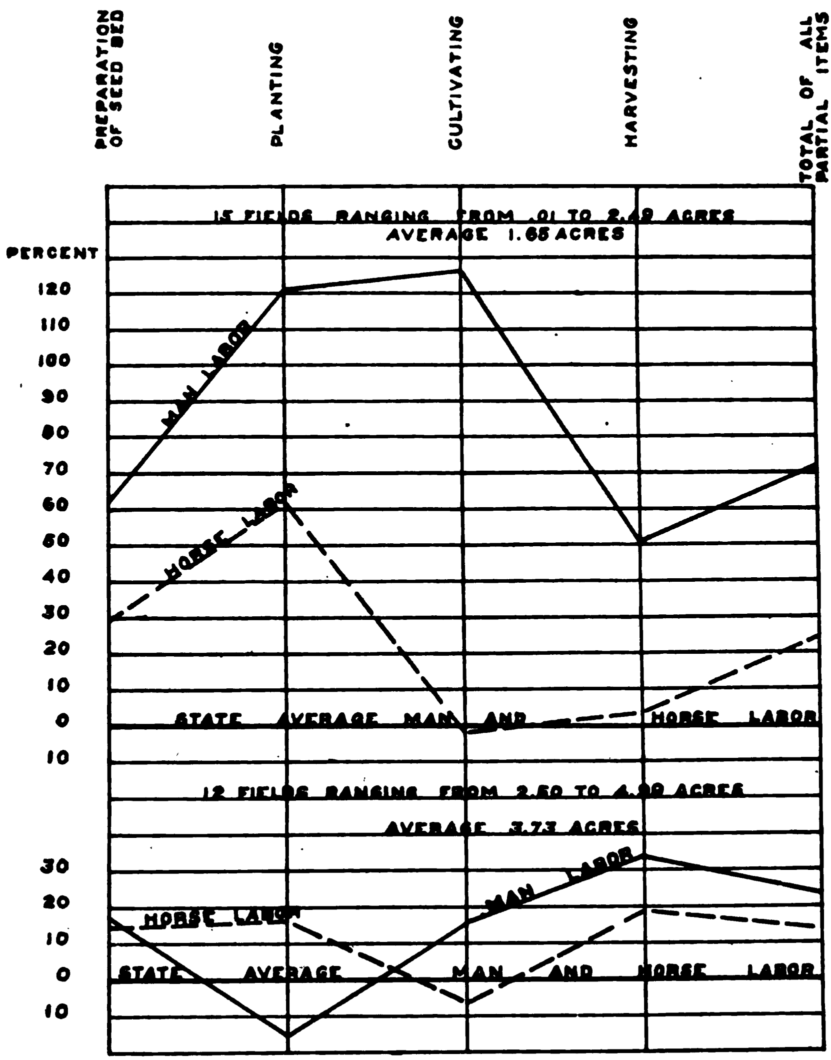

FIG. 7 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN VARIOUS SIZED FIELDS AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS AVERAGING 12.97 ACRES

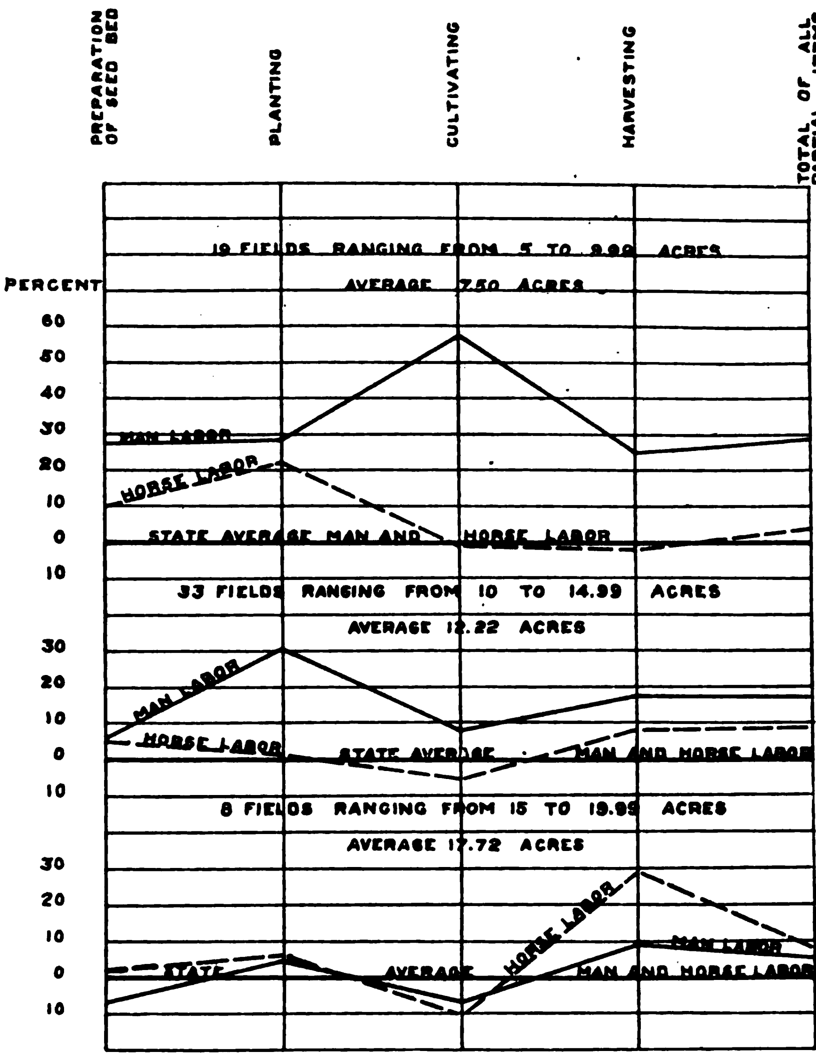

FIG. 8 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN VARIOUS SIZED FIELDS AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS AVERAGING 12.97 ACRES

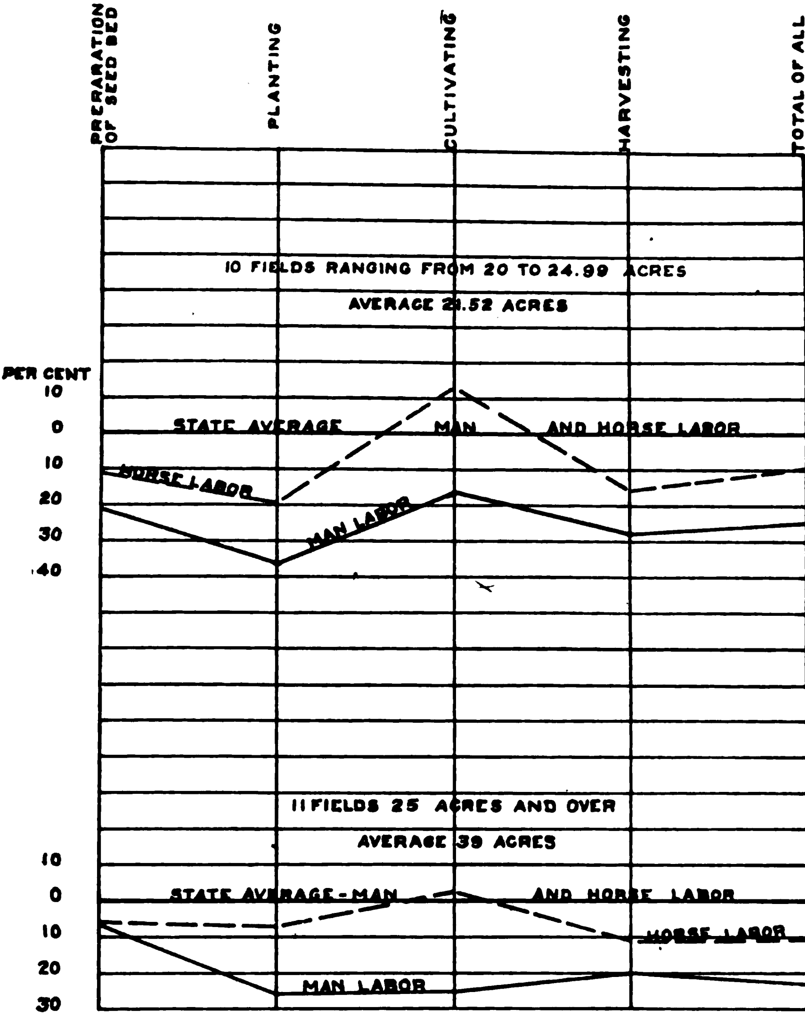

FIG. 9 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN IN VARIOUS SIZED FIELDS AS COMPARED WITH THE STATE AVERAGE OF 108 FIELDS AVERAGING 12.97 ACRES

TABLE XIII: Showing fields classified by size and location in the state.

Group division, acres	Total number of fields in group	Total area of all fields in group	Southeast		Northeast		Northwest		Southwest	
			Fields percent	Acres percent	Fields percent	Acres percent	Fields percent	Acres percent	Fields percent	Acres percent
.01-2.49	15	24.74	46.67	43.61	26.66	24.09	26.67	32 30	.....	.....
2.50-4.99	12	44.75	16.67	15.93	33.33	33.68	25.00	26.57	25.00	23.82
5.00-9.99	19	143.58	36 84	35.87	.....	.....	52.63	55 38	10 53	8.75
10.00-14.99	33	403.22	36.36	36 02	3.03	3.58	51.52	51.07	9 09	9.33
15.00-19.99	8	141.77	25.00	22.61	.....	.....	50.00	50.52	25 00	26.87
20.00-24 99	10	215.17	.....	.....	.....	.....	40.00	40.21	60.00	59.79

This table shows that, in any grouping of fields according to size, one region may predominate and hence the custom prevailing in the predominating region will greatly influence the total cost in that group. This is shown to a marked degree in the group .01 to 2.49 acres. In this group practically 47 percent of all the fields are in the Southeast section, and as shown in Table X, this section has the highest labor cost regardless of the size of the fields.

Further study of Figures 7, 8 and 9 or of Table XII reveals two pronounced cases in which the amount of man labor does not vary in accordance with the size of the fields. One is the time required for planting the fields averaging 3.73 acres, and the other is that required for cultivating the fields averaging 7.50 acres. Thesel exceptions are due, in a large measure at least, to the cultura methods. It so happens that in the first case all of the fields included were either drilled or planted with a check row planter. No time was spent in "marking out", and only one field had any replanting and that amounted to only one-half hour. In the second case, Table XIII shows that 37 percent of the fields are in the Southeast section, and 53 percent in the Northwest section. In both of these sections considerable hand labor (hoeing) was done. In fact, in all but 5 of the 19 fields included in the group averaging 7.50 acres, the hoe was used extensively as an implement of tillage; the average time of hoeing for all of the fields when used as explained in the footnote to Table XVIII on page 120 was 7.44 hours per acre, or 9.86 hours per acre for the fields in which hoeing was actually done. As these records cover a series of years and the fields are in various sections of the State, it is hardly probable that the climatic conditions were such as to require this amount of hoeing, or even a very large portion of it, in addition to the usual cultivation.

In Figure 7 the curve for the fields averaging 1.65 acres, shows that the man labor exceeds the horse labor in every partial item, varying from 50 to 126 percent. This of course indicates that a large amount of hand labor was done on these fields. However, where only a small acreage is grown annually the cost of hand labor may

be less than the interest on investment, taxes, insurance, depreciation and repairs on improved machinery, together with the cost of the horse labor necessary to operate the machinery.

The data at hand are not sufficient to justify the drawing of any conclusions when the fields are classified according to size in a given section, and compared with the average of all the fields in that section. However, charts (not shown here) which have been prepared from such data, seem to indicate that the size of fields in any section bears approximately the same relation to the average of that section as the average of any size in the State bears to the average of all the fields in the State. (See Figures 7, 8 and 9.)

SHAPE OF FIELDS

Another factor, which is more or less important in the labor cost of producing corn, is the shape of the field. Obviously, the shape of the farm has much to do with the shape and arrangement of the fields. Here again topography must be considered, since the fences frequently follow the contours of the surface. Fields having four sides, no two of which are parallel, or many sided and irregular shaped fields, naturally have a great many "point rows." With heavy horses and implements or with three, four or five horse teams, considerable time is lost in making the extra turnings due to these point rows.

Of the 108 fields under consideration, we have been able to classify 53 percent as rectangular. Comparing the average of all the rectangular fields with the average of all the other fields, we find but little difference in the labor required. But, by reclassifying these according to area, it is found that, generally speaking, there is a difference in the amount of labor required in favor of the rectangular fields. In Figure 10 it is shown that in the group of 15 fields averaging 1.65 acres the total labor cost of the rectangular fields is less than of the misshapen ones, but this is not uniformly true of the various partial items in this group. This may be due to the fact that the work is largely hand labor, which should not vary a great deal with the shape of the field. The 12 fields averaging 3.73 acres (shown in Figure 7 but not shown in Figure 10) have only a few fields which are not rectangular, so no comparison can be made. Likewise, no comparison can be made in the group averaging 17.72 acres (shown in Figure 8 but not shown in Figure 11) because there is only one rectangular field in this group. In the groups averaging 7.50 acres (Figure 10), 12.22 acres and 21.52 acres (Figure 11) it will be observed that in every case the labor cost of the rectangular fields is considerably lower than that of the misshapen ones. Table XIV gives in tabular form the same data as are shown by Figures 10 and 11.

TABLE XIV. Showing relative amount of labor expended per acre in growing corn on rectangular and misshapen fields of various sizes, and the percentage variation from the State average for groups of the same size.

Field groupings and partial items	Man hours					Horse hours				
	Rectangular fields		Misshapen fields		State average	Rectangular fields		Misshapen fields		State average
	Hours per acre	Variation percent	Hours per acre	Variation percent		Hours per acre	Variation percent	Hours per acre	Variation percent	
Fields ranging from .01-2.49 A.	10 fields, av. 1.70 A.		5 fields, av. 1.54 A.		15 fields, av. 1.65 A.	10 fields, av. 1.70 A.		5 fields, 1.54 A.		15 fields, av. 1.65 A.
Preparation of seed bed	11 26	−13	16.48	28	12.89	23.52	−12	33.71	26	26.69
Planting	4.38	11	2.96	−25	3.94	3 39	3	3 05	−7	3.28
Cultivating	21.80	−3	23.82	6	22.43	12 60	−2	13 62	5	12.92
Harvesting	33.31	5	28.09	−11	31.69	12.84	−1	13.07	..	12.91
Total*	83.58	−1	87.47	3	84.79	66.22	−4	75.84	10	69.21
Fields ranging from 5.00-9.99 A.	10 fields, av. 7.36 A.		9 fields, av. 7.67 A.		19 fields, av. 7.50 A.	10 fields, av. 7.36 A.		9 fields, av. 7.67 A.		19 fields, av. 7.50 A.
Preparation of seed bed	8.86	−12	11.34	13	10.06	20.04	−11	25.28	12	22.58
Planting	1.98	−14	2.61	14	2.29	2.40	−3	2 55	3	2 47
Cultivating	13.16	−15	18.13	16	15.57	12.03	−8	13.99	7	13.03
Harvesting	27.22	4	25.09	−4	26.19	12.43	2	11.94	−2	12.19
Total*	57.45	−7	66.91	8	62.03	50.31	−13	65.08	13	57.72
Fields ranging from 10.00-14.99 A.	19 fields, av. 12.50 A.		14 fields, av. 11.33 A.		33 fields, av. 12.22 A.	19 fields, av. 12.50 A.		14 fields, av. 11.33 A.		33 fields, av. 12.22 A.
Preparation of seed bed	7.81	−1	9.24	1	8.40	19.81	−8	24 31	12	21.66
Planting	2.35	1	2.29	−2	2.33	1.98	−3	2.14	4	2.05
Cultivating	9.84	−8	11.91	11	10.69	12.21	−2	12.88	3	12 49
Harvesting	23.73	−4	25.94	5	24.64	13 59	1	13.18	2	13 43
Total*	53.55	−5	61.06	8	56.63	57.02	−6	65.57	8	60.53
Fields ranging from 20.00-24.99 A.	4 fields, av. 20.84 A.		6 fields, av. 21.96 A.		10 fields, av. 21.52 A.	4 fields, av. 20.84 A.		6 fields, av. 21.96 A.		10 fields, av. 21.52 A.
Preparation of seed bed	5.75	−8	6.54	5	6.23	18.64	2	18.06	−1	18.28
Planting	.97	−14	1.23	9	1.13	1.46	−10	1.73	6	1.63
Cultivating	7.17	−14	9 02	9	8.31	14.90	..	14.92	..	14.91
Harvesting	9.02	−40	19.00	25	15.14	6.06	−42	13.25	27	10.46
Total*	22.91	−37	42 48	17	36.20	41.04	−18	53.78	7	50.07

*See foot note to Table XI.

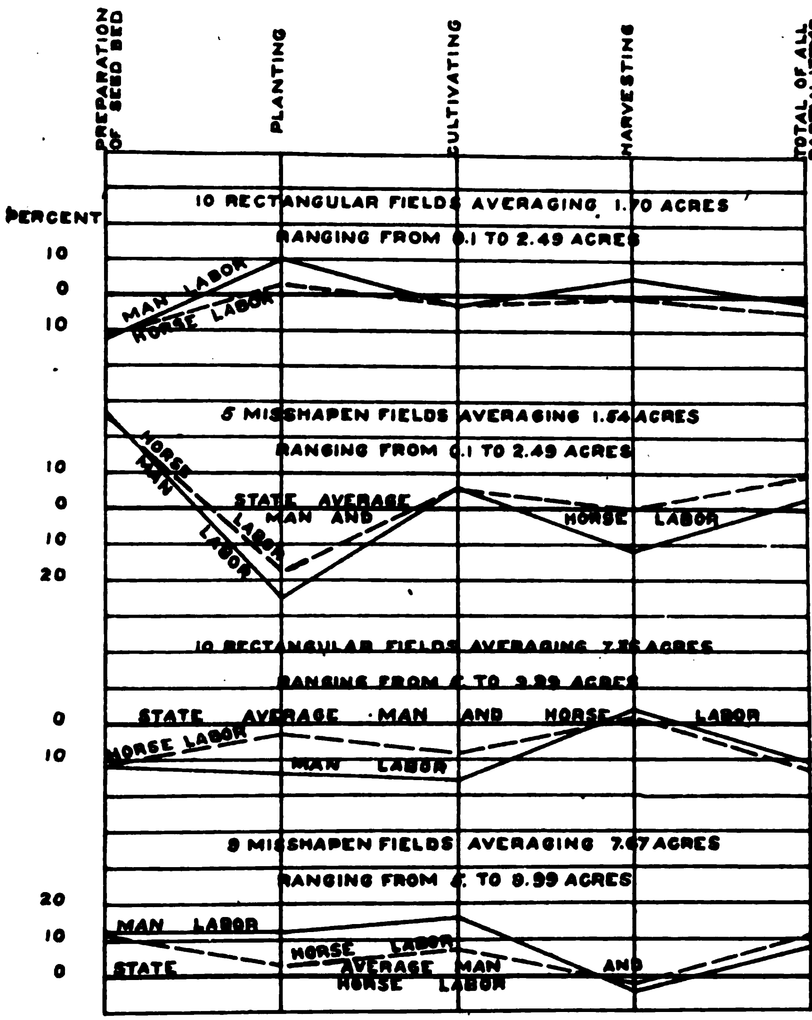

FIG. 10 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN ON RECTANGULAR AND MISSHAPEN FIELDS AS COMPARED WITH THE STATE AVERAGE OF FIELDS OF SIMILAR SIZE

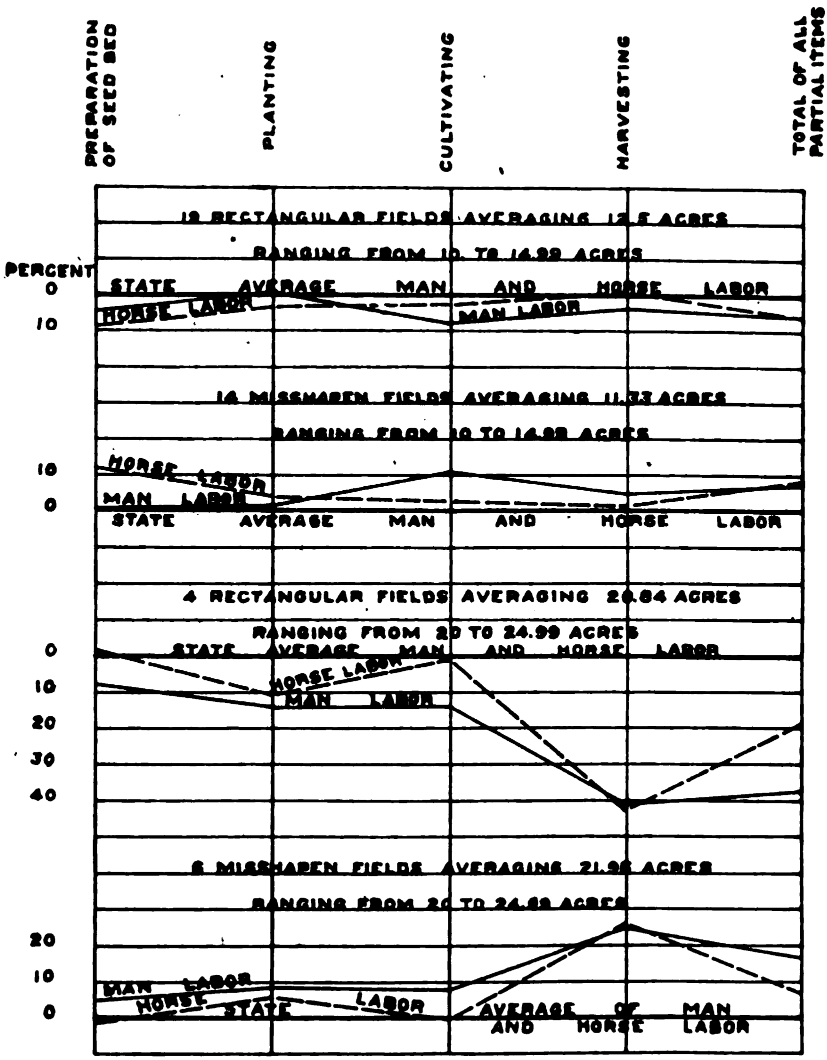

FIG. 11 CURVES SHOWING RELATIVE AMOUNT OF LABOR EXPENDED PER ACRE IN GROWING CORN ON RECTANGULAR AND MISSHAPEN FIELDS AS COMPARED WITH THE STATE AVERAGE OF FIELDS OF SIMILAR SIZE

In comparing the ratio of the width to the length of rectangular fields it is found that where the length is three times the width the total labor cost is less than where it is twice the width; where the length is twice the width the labor cost is less than where the sides are more nearly of equal length. This, however, is not uniformly true for each partial item.

TABLE XV: Showing that the method by which the crop is harvested has no appreciable effect on the labor cost of the partial items.

		Average of all fields shown in Table III	Average of all fields harvested by same general method as those of Table III	Average of all fields harvested in any manner whatsoever
Applying fertilizer:	Number of fields	82	97	153
	Average size of field: acres	12.79	12.40	12.50
	Hours per acre—man	3.48	5.27	4.83
	Hours per acre—horse	8.43	8.29	7.52
Care of seed:	Number of fields	82	89	144
	Average size of field: acres	14.29	13.84	13.50
	Hours per acre—man	.82	.79	.81
	Hours per acre—horse	.08	.08	.08
Preparation of seed bed:	Number of fields	108	122	202
	Average size of field: acres	12.97	12.53	12.65
	Hours per acre—man	7.92	8.07	8.58
	Hours per acre—horse	20.58	20.62	21.69
Planting:	Number of fields	108	125	204
	Average size of field: acres	12.97	12.68	12.77
	Hours per acre—man	1.78	1.79	1.83
	Hours per acre—horse	2.02	2.07	2.12
Cultivating:	Number of fields	108	125	204
	Average size of field: acres	12.97	12.68	12.75
	Hours per acre—man	9.89	9.95	9.81
	Hours per acre—horse	13.16	12.87	12.86
Harvesting:	Number of fields	108	121	180
	Average size of field: acres	12.97	12.84	13.30
	Hours per acre—man	20.98	20.89	20.69
	Hours per acre—horse	12.40	12.39	13.10
Miscellaneous labor:	Number of fields	27	38	68
	Average size of field: acres	10.53	10.30	10.89
	Hours per acre—man	.34	.53	.58
	Hours per acre—horse	.12	.24	.26
General farm labor:	Number of fields	108	125	205
	Average size of field: acres	12.97	12.68	12.74
	Hours per acre—man	2.82	2.88	2.68
	Hours per acre—horse	.90	.88	.86

In making a study of partial items the question also arises whether or not the manner in which the crop is to be harvested has any effect upon the time required to prepare the seed bed, plant or cultivate the crop. For example, if a field is to be hogged off will the farmer spend less time in cultivating that field than he would a field which he is expecting to put in the silo or cut and husk in some manner? Table XV, showing the actual average time per acre, compares item by item the average of the fields shown in Table III (1) with all fields harvested in the same general method, regardless of any variation in the number of fields

in each partial item, and (2) with all fields, regardless of the method in which they were handled or harvested. This table shows that the method of harvesting has no appreciable effect on the other partial items, such as preparing the seed bed, planting, cultivating, etc. This being the case, the larger number of fields will be used in discussing both the partial item labor costs and also the cost per acre, once over, of the various operations. The variation in the number of fields and in the average size of fields is due to the fact that in any particular partial item, only those fields actually operated upon are considered. The acreage is not the same in all the partial items for various reasons. Climatic conditions during the summer and fall may, for example, decrease the harvested area as compared with that which was prepared or planted. Or again, not all farmers manure or fertilize their corn ground; nor do all test or grade their seed corn. These and similar reasons account for the variations just mentioned.

Fig. 12. Efficient use of labor.

In studying these various partial items, a number of interesting features and comparisons are found. Harvesting is the largest single item. The man labor in harvesting amounts to more than 40 percent of the total man labor required to produce the crop, while the combined man and horse labor cost in this item is approximately 34 percent of the total labor cost. If the average hours of labor shown in Table IV (23.38 man and 41.21 horse) be subtracted from the average of Table III (48.18 man and 55.44 horse), the difference, 24.80 man hours and 14.23 horse hours, represents the time

required for harvesting, a large part of which is saved when the corn is hogged off. These figures for harvesting are much the same as given in Table XV. If both are reduced to a money basis, it is found that the cost of harvesting, as determined by subtraction, exceeds that as shown in Table XV by only 75 cents per acre. (If the hours shown in Table IV be subtracted from the averages mentioned on page 97 (46.12 man and 55.37 horse) the time remaining for harvesting is 22.74 man hours and 14.16 horse hours or 41 cents per acre, more than the average shown in Table XV.)

Fig. 13. A method of harrowing for corn still practiced in some sections of Ohio.

The average yield of 87 of the 108 fields under consideration was 48.13 bushels per acre. Forty-four of these fields produced less than this, or an average of 36.57 bushels per acre, while 43 fields produced an average of 59.38 bushels per acre. Table XVI shows the labor cost of harvesting, as well as the total labor cost of these fields when classified according to yields per acre. From this table it will be seen that the total labor cost of the 43 fields having the average yield of 59.38 bushels per acre is but 50 cents per acre more than that of the 44 fields averaging only 36.57 bushels per acre, thus making the labor cost per bushel very much lower for the 43 fields having the higher yield. Likewise, it will be seen that the labor cost does not increase correspondingly as the yield per acre increases, and the labor cost per bushel of course constantly decreases, until the yield of 74.85 bushels per acre is reached. It is probable that the high labor cost per bushel in the last class is not typical because of the smaller number of fields in the class and is caused largely by the smaller acreage of the fields and the much greater amount of hand labor on some of them.

TABLE XVI: Showing labor required for harvesting and total labor required for producing corn on fields classified according to yield.

Classification	Number of fields	Average size of fields	Labor cost per acre of harvesting			Total labor cost per acre			Average yield per acre	Total labor cost per bu.
			Man hours	Horse-hours	Cost at 16c and 8c	Man hours	Horse hours	Cost at 16c and 8c		
Fields producing less than 48 bu. per acre.........	44	11 75	20.66	12.06	$4.27	49.42	55.14	$ 12.32	36 57	33 7c
Fields producing more than 48 bu. per acre.......	43	12 15	22.63	13.83	4.73	50.37	58.28	12.72	59.38	21.4c
Fields producing less than 30 bu. per acre	8	8 89	26.10	15.00	5.38	52.81	56.02	12.93	21.08	61.3c
Fields producing 30 and less than 40 bu. per acre.	16	13 77	17.62	9.77	3.60	41 37	50.78	10.68	33.96	31 4c
Fields producing 40 and less than 50 bu. per acre..	24	11.44	21 38	13.43	4.50	53 81	57.90	13.24	45.29	29.2c
Fields producing 50 and less than 60 bu. per acre .	17	14 35	22.82	11 52	4.57	47.90	51 13	11.75	55.29	21.3c
Fields producing 60 and less than 70 bu. per acre.	17	11 89	20.77	16.33	4 63	49.48	64 91	13.11	64.70	20.3c
Fields producing 70 bushels and over	5	5.40	41.44	1.60	6.76	92.75	83.79	21.54	74.85	28.8c

After harvesting, cultivation is the next largest item in reference to man labor, but preparation of the seed bed exceeds it in both the hours of horse labor and the total labor cost. The following table shows the ranking of the various partial items in hours of labor and also the approximate percentage each is of the total labor cost.

TABLE XVII: Showing labor relation of different partial items to each other.

Partial item	Approximate percent of total labor cost	Relative rank of amount of labor used		Hours of horse labor used per hour of man labor
		Man	Horse	
Harvesting	34	1	2	.63
Preparing seed bed	24	3	1	2.53
Cultivating	21	2	3	1.31
Fertilizing	11	4	4	1.56
Overhead labor ("General Farm")	4	5	6	.32
Planting	4	6	5	1.16
Care of seed	1	7	8	.01
Miscellaneous labor	1	8	7	.45

The preceding table, together with Table XV, reveals the fact that the overhead labor charge, or general farm labor, is considerably more than is generally supposed. In fact, it is usually disregarded entirely by farmers, whereas these figures show the overhead man labor per acre to be about 46 percent more than that required for planting; approximately one-third the time required to prepare the seed bed, and more than one-third the time of cultivating, yet all of these are well known operations in the production of corn, the importance of the cost of which no one will dispute.

By referring to Tables III, IV, V and VI on pages 95 and 96, it will be seen that with the exception of "hogged off" corn—Table IV—the total man hours nearly equal the total horse hours, and even where the harvesting is omitted there are less than two horse hours used per hour of man labor. This indicates that a great deal of hand labor is being done and that in some operations at least the horse labor is not being used to the best advantage. Table XVII shows that only a few of the partial items have much more than one horse hour per hour of man labor.

In Table XV were shown the partial item costs for all fields on which any work in connection with any particular partial item was performed, regardless of the times over or the acres covered. Table XVIII shows the labor cost per acre once over, of the more important operations.

TABLE XVIII: Labor required per acre, once over.

Operation	Total acres	Total hours		Hours per acre	
		Man	Horse	Man	Horse
Manure	662.73	7,816.72	11,697.14	11.79	17.65
Manure[1]	1,956.32	11,574.97	17 869.89	5.92	9.13
Care of seed	1 943.62	1 578.00	161.07	.81	.08
Preparation of seed bed:					
Plowing	2,654.70	14,428.38	34,929.85	5.44	13.16
Harrowing (spike)	3,210.41	3,170.48	8,617.71	.99	2.68
Discing	1,908.55	1,946.10	5,648.30	1.02	2.96
Planking	1,071.38	1,000.75	2 691.50	.93	2.51
Rolling[2]	842.64	641.00	1 353.25	.76	1 61
Planting:					
Marking out—1 horse	74.76	117.75	117.75	1.58	1.58
" " 2 horses	164.05	124.75	249.50	.76	1.52
Planting by hand	43.06	102.50	......	2.38	....
Drilling	224.10	335.50	407.00	1.50	1.82
Planting (2 horses)	1,592.79	1,488.00	2,975.00	.93	1.86
Replanting	638.73	1,183.25	....	1.85	....
Replanting[1]	1 158.67	1 354.75	....	1.17	....
Cultivating:					
Harrowing after planting	493.40	348.00	808.00	.71	1.64
Rolling after planting	368.01	259.00	515.00	.70	1.40
Using weeder	292.00	214.73	214.73	.74	.74
Cultivating (2 horses)	2,788.19	4,675.00	9,350.00	1.68	3.36
Hoeing	459 16	5,615.75	....	12.23	....
Hoeing[1]	1 649.67	7 792.50	....	4.72	....
Harvesting:					
Cutting by hand	576.66	5,226.50	....	9.06	....
Cutting by machine	565.62	1,428.37	2 181.62	2.53	3.86
Cutting silage corn by machine	95.79	247.63	479.13	2.59	5.00
Shocking	414.52	1,463.00	......	3.53	....
Picking up ear corn after binder	267.44	429.50	596.00	1.61	2.23
Filling silo[3]	144.50	3,356.63	2,818.38	23.23	19.50
Husking by hand	555.49	8,004.50	......	14.41	....
Hauling corn[4]	715.51	2 788.00	4,618.25	3.90	6.45
Hauling fodder[4]	348.80	853.75	1,165.00	2.45	3.34
Snapping, jerking and husking from stalk	156.93	1,690.75	2,165 25	10.77	13.80
Husking and shredding	353.30	4 497.75	4 245.75	12.73	12.02
Shredding	121.41	600.50	525.50	4 95	4.33
Hauling shock corn	31.48	225.00	285.00	7.15	9.05
Hauling fodder for feed[5]	140.02	842.00	1 234.00	6.01	8.81

[1]This includes the fields in the preceding item and in addition those in which only a part of the area was covered. The total area of fields, even though partly untreated, has been used in the calculations in connection with this item.

[2]The man hours include some labor done by boys which has been reduced to the equivalent of man time.

[3]Includes the time for cutting the corn in the field.

[4]After corn has been husked from shock in field.

[5]Only one farm. The time shown doubtless includes time required to feed fodder to cattle.

In studying the preceding table in connection with Table XV, it is found that the man labor of plowing is 63 percent and the horse labor 61 percent, respectively, of the labor of preparing the seed bed. In planting it is seen that the man labor per acre of replanting is more than is required to make the first planting by machine. Replanting was done on 86 out of 168 fields, hence it is an item of considerable importance as judged by the farms under consideration. If this time of replanting had been spent in testing and repairing the planter, testing seed corn, etc., during the period when crop work was at a standstill, a great deal of valuable time could doubtless have been put on other crops during the growing season, to say nothing about the more uniform stand of corn.

A few points in connection with the cultivation of corn as pronounced by Table XVIII deserve special mention. Out of a total of 204 fields there were 133 fields, with a total of 1,649.67 acres, on which the hoeing amounted to 4.72 hours per acre for the entire area, as explained in the foot note. This includes a total of 384.25 man hours for uncovering, setting up and thinning. Of these 133 fields there were 55, with a total of 459.16 acres, on which the average time of hoeing the entire area was 12.23 man hours. On dividing the total time for hoeing (7,792.5 man hours) by the total acreage (2,600.98) of the 204 fields cultivated, it is found that the hoeing amounts to 3 man hours per acre, which is practically 31 percent of the total man labor (9.81 hours) or 18 percent of the total labor cost of cultivation. From these figures it is manifest that a vast amount of hand labor, especially in cultivating, is being done. The experience of some of those men who have cooperated in this work proves that if only a part of this time be spent in more thorough preparation of the seed bed and in the cultivation, other than hoeing, of the crop, the profits will be equally as great and the task not so disagreeable.

As previously stated, it is the purpose of this Bulletin to discuss some of the phases of the labor cost of producing corn. However, in order that an approximate total cost may be determined, the following table based upon our records is added.

TABLE XIX: Costs other than labor—per acre.

Item	Number of fields reported	Minimum	Maximum	Average of all
Value of fertilizer applied	73	$ .62	$ 4.01	$ 1.46
Value of seed used	173	.05	2.32	.28
Value of twine used	70	.08	.38	.18
Machinery cost	176	.30	4.12	1.34
Land rental	170	1.27	6.88	3.81
General farm cash expense	128	.03	1.99	.42
Husking and shredding charge	18	1.00	2.91	1.97
Shredding charge	13	.46	.86	.61
Filling silo	5	1.24	1.61	1.36
Fuel	36	.03	.57	.25

The foregoing are the figures as they have been worked out for the various farms, but since no definite study of them has been made, they are not presented with the idea that they are surely correct. They are given more as a basis on which to make estimates. However, upon comparison it is found that they are not materially different from the figures presented in Bulletin No. 73, of the Bureau of Statistics, U. S. Department of Agriculture.

In the preceding table the item of land rental is based on the inventoried value of the farms under consideration. The average figure is doubtless somewhat low, owing to the fact that a part of

the farms on which this work was done are in sections of the State where land in general is cheaper, and the inventories are of the entire farm rather than of the more valuable fields on which the corn was grown. In the typical corn belt region of Ohio, farms rent at from five to seven dollars per acre for the entire acreage.

Fig. 14. Methods of cultivating corn as practised in Ohio. (A) Not common, but seen occasionally. (B) Inefficient use of man labor. (C) A quite common method, although the two-row worker is being rapidly introduced.

The preceding table has not taken into consideration the item of interest on the "cost until the crop yields a return," or the item of "insurance" against plant diseases, insects, floods, hailstorms and other weather conditions. This last item, like the first, is not actually paid for in cash, yet a certain percentage of the yield should be

leducted for insurance before figuring any profits. The value of the yield deducted should be allowed to accumulate as a fund to be drawn rom when the crop fails or is damaged by some factor over which he producer has no control. The percentage of the yield to be leducted for insurance will depend upon the yield that is expected nnually. The higher this gets above the average production of the tate the greater should be the percentage set aside for insurance. 'he large yields per acre, which farmers have in mind when figur- ıg costs, rarely ever materialize on the entire acreage planted. 'ne hundred bushel yields by weight of merchantable corn are rare ıdeed; 75 bushel yields are not at all frequent.

While some of these items of cost seem of minor importance, ɜt all are items which must be considered before any profits can be ;ured. The failure to consider them misleads many people in ;uring the cost of production upon their farms. The average field corn in Ohio probably costs more than it is worth, unless the oducer figures his labor at a very low rate.

SUMMARY

The labor cost is the largest single item in the total cost of ›ducing corn.

From the fields under consideration it is found that the total or required is 48.18 man hours and 55.44 horse hours; or. at 16 ıts per hour for man and 8 cents per hour for horse labor, the t is $12.14 per acre.

The cost in the different sections of the State, figured at 16c man and 8c for horse labor is: For the Southwest section, $9.62; the Northwest section, $12.46; for the Northeast section, $16.28; the Southeast section, $16.76.

Replies from 34 Ohio municipalities having an average population ,831 show the average wage per hour for common laborers to be roximately 19c; for the common laborer with team, 44c. When red at these rates the labor cost per acre of producing ı for the State is $16.08; for the Southwest section, $12.87; the Northwest section, $16.46; for the Northeast section, $21.33, for the Southeast section, $22.01.

In many cases the crop yield is not sufficient to pay for the le item of labor required to produce it unless the labor is figured ı extremely low rate.

Within certain limits, at least, the labor cost per acre is less on ɜ fields than on small ones.

The man labor per acre of replanting, which is still a common custom, is more than is required to make the first planting by machine.

A large amount of hand labor, especially in cultivating, is done on the corn crop. It would seem that much of this could well be avoided.

The labor cost of harvesting is more than one-third the total labor cost. An appreciable amount of labor is therefore saved when the crop is harvested by livestock in the field.

THE VALUE OF SOYBEAN AND ALFALFA HAY IN MILK PRODUCTION

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., DECEMBER, 1913

BULLETIN 267

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BULLETIN

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Ohio Agricultural Experiment Station

NUMBER 267 DECEMBER, 1913

THE VALUE OF SOYBEAN AND ALFALFA HAY IN MILK PRODUCTION

BY R. E. CALDWELL*

INTRODUCTION

The purchase of nitrogenous feeds for dairy cows has in recent years assumed enormous proportions. As a general rule, these feeds are concentrates, such as the by-products: bran, middlings, linseed oil meal, cotton-seed oil meal, gluten feed and distillers' grains. Several of these with other feeds and filling materials have been mixed to form the so-called "ready to use" rations that are being rather widely distributed. The prevailing high prices of feeds in general and the great demand for feeds suitable for dairy cows have caused prices for these feeds to become very high; so high, in fact, that some dairymen have come to feel that they can scarcely afford to purchase them. The question naturally arises, "Must these feeds be used in order to produce dairy products at a profit, or may home-grown feeds be used in their places?" It is obvious that no answer can be given that will apply to all conditions. However, in order to ecure data which may assist feeders to determine which course is est suited to the conditions with which they are dealing, two xperiments have been conducted at this Station to compare such itions. The first will be discussed in Part I, and the second in art II of this bulletin.

PLAN

The first experiment was planned to compare soybean hay with an and cotton-seed meal as a source of protein. This experiment nsisted of two tests; one conducted in 1908 and the other in 1909.

*Resigned October 5, 1911.

PART I

In selecting animals for this test, the following points were considered: producing capacity, breed, age, period of lactation and duration of pregnancy. Eleven cows were used in the 1908 test and nine in the 1909 test.

Tables I and II give the exact data regarding the points considered in the selection of the cows for these tests. These tables show that the two lots were quite similar, and the comparisons obtained are believed to be fair.

TABLE I. Cows used in the 1908 test.

Name of cow	Breed	Age yrs.-mos.	Date of calving	Date bred	Production of milk per day
Lot 1					Lbs.
Miami Pride...........	Guernsey	10-8	Nov. 21, 1907	Feb. 8, 1908	25.65
Topsy May............	Jersey	6-0	Oct. 13, 1907	Feb. 27, 1908	19.35
Mantee Mahomet......	Holstein	4-9	Oct. 7, 1907	Mar. 9, 1908	20.56
Teeny Gray 2nd......	Jersey	2-9	Sept. 15, 1907	Jan. 11, 1908	14.67
Little May......	Jersey	6-4	Aug. 29, 1907	Oct. 13, 1907	17.48
Average..........		5-8	....	....	19.54
Lot 2					
May's 2nd..........	Jersey	11-11	Nov. 9, 1907	....	21.25
Phillip's 4th...... ..	G. Guernsey	9-11	Nov. 10, 1907	Mar. 29, 1908	21.51
Grace Daw	Holstein	6-10	Sept. 23, 1907	Feb. 15, 1908	24.82
Fair Mahomet........	Holstein	2-8	Sept. 12, 1907	Jan. 16, 1908	21.18
May 2nd Pedro.......	Jersey	4-0	Aug. 17, 1907	Mar. 9, 1908	12.45
Bessie Nervillette......	Jersey	4-7	Dec. 4, 1907	Feb. 4, 1908	21.39
Average.	....	8-8	....	....	20.43

TABLE II. Cows used in the 1909 test.

Name of cow	Breed	Age yrs.-mos.	Date of calving	Date bred	Production of milk per day
Lot 1					Lbs.
Grace Daw	Holstein	7-10	Nov. 16, 1908	Mar. 18, 1909	35.08
B. Nervilette......	Jersey	5-7	Nov. 18, 1908	Feb. 17, 1909	21.68
May 2nd Pedro... ..	Jersey	5-5	Dec. 10, 1908	Mar. 26, 1909	24.85
Teeny Gray 2nd......	Jersey	3-9	Oct. 18, 1908	Jan. 23, 1909	16.46
Average...... ...	....	5-8	....	....	24.52
Lot 2					
Lady Thorne's 4th...	Holstein	3-9	July 30, 1908	Nov. 8, 1908	26.91
Fair Mahomet........	Holstein	3-8	Oct. 16, 1908	Feb. 28, 1909	23.60
Miami Pride......	Guernsey	11-8	Oct. 29, 1908	Mar. 26, 1909	29.14
Little May............	Jersey	7-4	July 20, 1908	Dec. 8, 1908	16.16
Topsy May..........	Jersey	7-0	Dec. 8, 1908	....	26.58
Average...........	....	6-6	....	....	26.26

During the entire time that the cows were under observation e milk of each cow was weighed and sampled separately at each lking. A container was provided for the samples from the milk each cow, and the composite samples thus obtained were tested ekly for butterfat. The feeds were analyzed under the direction Mr. J. W. Ames, chief in Chemistry at the Station, with results shown in the following tables:

TABLE III: Composition of feeds used in the 1908 test—Lbs. per 100.

Name of feed	Water	Ash	Protein	Fiber	Nitrogen-free extract	Ether extract
re	76.825	.958	1.891	5.467	13.506	1.360
ean hay	12.748	7.856	11.627	28 850	36.684	2.236
stover	20.252	4.383	4.248	26.931	42.141	2.045
ean hay, refuse	14.324	5.135	6 942	40.413	32.006	1.180
stover, refuse	26 592	3.642	2.760	31.562	33.816	1.628
on-seed meal	10.196	7.195	40.260	8.000	25.093	9.256
	12.920	5.692	15 320	8.747	53.996	3.325
meal	16.120	1.402	9.390	2.077	67.074	3.947

TABLE IV. Composition of feeds used in the 1909 test.—Lbs. per 100.

Name of feed	Water	Ash	Protein	Fiber	Nitrogen-free extract	Ether extract
e	68.36	1.26	2 20	8.12	19.24	.82
an hay	13.83	6.10	13.52	25.71	37.80	3.04
stover	12.22	5.24	5.73	26.25	49 00	1.56
an hay, refuse	16.76	4.69	10.51	32.25	33 56	2.23
, refuse	66.08	1.50	2.06	11.04	18.74	.58
Stover, refuse	24.16	3.73	3 74	27.24	39.89	1.24
n-seed meal	3.30	6.73	40.47	6.97	31.80	10.73
	13.35	4.99	13.88	7.06	56.98	3.74
meal	17.93	1.25	7.51	1.87	68.15	3.29

There was a slight difference in the composition of the feeds l in the two experiments. The moisture in the silage used for two tests varied somewhat over 8 percent; the cotton-seed meal also found to contain much less moisture in the second test 9) than in the first test (1908); otherwise, the composition of the ous feeds for the two tests was quite similar.

In both tests the rations for the corresponding lots were the e, and were as follows: Lot 1 in both tests received corn silage, ean hay, and a grain mixture made up of 6 parts, by weight, of meal and 1 part of cotton-seed meal. Lot 2 in both tests ived corn silage, corn stover and a grain mixture made up of 1 parts, by weight, of corn meal, wheat bran and cotton-seed

It will be noticed that, in both cases, Lot 1 received a ration in h a very small amount of purchased feed was used; while a ively large amount of both bran and cotton-seed meal were used e ration supplied to Lot 2 in both tests. The plan of feeding

during the preliminary and subsequent periods was the same except in the period subsequent to the second test, in which case two cows of Lot 1 were continued on soybean hay and two cows of Lot 2 were continued on bran and cotton-seed meal; while the remainder of both lots received mixed hay and silage as a roughage and corn and cotton-seed meal as grain.

The following prices of feeds and product were used in all calculations:

Wheat bran	$24.00	per ton
Corn meal	20.00	" "
Cotton-seed meal	30.00	" "
Corn silage	3.00	" "
Corn stover	4.00	" "
Soybean hay	8.00	" "
Alfalfa hay	10.00	" "
Milk (whole)	1.00	per cwt.
Milk (skim)	.15	" "
Butterfat	.25	per lb.

RESULTS OF THE FIRST TEST

In order to obtain definite data as to the performance of the various individuals when fed similarly, all cows in this test were fed for the preliminary period of 31 days the same ration received by Lot 1 during the test. They were then divided into two lots as shown in Table I, and were fed the rations given above. The comparison proper continued for 60 days and subsequent records were kept for 30 days, making in all 121 days.

FEEDS CONSUMED

Table V shows the amount of feed consumed by each lot during the 60 days.

TABLE V. Feed consumed during 60 days test, 1908.

Lot 1. Ration during test: corn silage, soybean hay, corn and cotton-seed meal.

Name of cow	Total lbs. feed consumed				Average daily lbs. feed consumed			
	Corn meal	Cotton-seed meal	Silage	Soybean hay	Corn meal	Cotton-seed meal	Silage	Soybean hay
Miami Pride	364.8	60.8	2,098	515	6.08	1.01	34.96	8.58
Topsy May	308.4	51.4	2,100	570	5.14	.86	35.00	9.51
Mantee Mahomet	358.8	59.8	2,029	448	5.98	.99	33.82	7.47
Teeney Gray 2nd	308.4	51.4	1,924	504	5.14	.86	32.06	8.41
Little May	308.4	51.4	1,891	525	5.14	.86	31.53	8.76
Average	329.7	54.9	2,008	512	5.49	.91	33.47	8.54

TABLE V. Concluded. Feed consumed during 60 days test, 1908.

Lot 2. Ration during test: corn silage, corn stover, corn, bran and cotton-seed meal										
Name of cow	Total lbs. feed consumed					Av. daily lbs. feed consumed				
	Bran	Corn meal	Cotton-seed meal	Silage	Corn stover	Bran	Corn meal	Cotton-seed meal	Silage	Corn stover
ʼlay's 2nd........	172	172	172	2,098	464	2.86	2.86	2.86	34.96	7.74
ʼhillip's 4th......	150	150	150	2,100	459	2.50	2.50	2.50	35.00	7.65
;race Daw........	172	172	172	2,100	508	2.86	2.86	2.86	35.00	8.46
ʼair Mahomet....	172	172	172	2,088	400	2.86	2.86	2.86	34.81	6.67
ʼlay 2nd Pedro...	150	150	150	2,050	538	2.50	2.50	2.50	34.17	6.43
ʼessie Nervilette..	150	150	150	2,095	441	2.50	2.50	2.50	31.53	8.76
Average.......	161	161	161	2,088	468	2.68	2.68	2.68	34.24	7.61

This table shows that the silage consumed per day was slightly ·reater in Lot 2 though the difference amounted to little. Lot 1 onsumed somewhat more of the soybean hay than did Lot 2 of the tover. Less of the soybean hay was refused than of the stover.)wing to the coarse nature of these feeds, a large percentage of each ·as refused. The total number of pounds of grain consumed daily ·as greater with Lot 2, and these grains were the most expensive. 'he total amount of nutrients consumed by the two lots was ractically the same.

The average daily nutrients consumed is shown in Table VI; lso the composition of an average daily ration. Lot 2 received ightly more protein and fat, yet it is interesting to note how closely ıe two rations agree in total composition.

TABLE VI: Average daily nutrients consumed, 1908.

Name of cow	Protein (lbs.)	Crude fiber (lbs.)	Nitrogen-free extract (lbs.)	Ether extract (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal, cotton-seed meal				
ımi Pride	2.884	3.988	12.448	1.057
psy May..................	2.798	4.332	12.082	1.017
ntee Mahomet..............	2.749	3.523	11.848	1.018
·ny Gray 2nd..............	2.667	3.729	11.336	.964
tle May	2.681	3.841	11.374	.961
Average..................	2.756	3.883	11.818	1.003
Lot 2. Ration during test: corn silage, corn stover, bran, corn, cotton-seed meal				
·'s 2nd..................	2.943	4.255	12.683	1.133
llip's 4th..............	2.703	4.158	12.119	1.071
ce Daw	2.964	4.485	12.931	1.145
r Mahomet................	2.911	3.907	12.298	1.113
· 2nd Pedro	2.654	3.729	11.596	1.040
sie Nervilette............	2.693	4.060	12.273	1.066
Average..................	2.811	4.099	12.272	1.095

While there was some difference in the average daily production, it continued through all three periods. This with the equal amount of nutrients consumed must not be taken as proof that the nutrients in a given amount of roughage are equal in food value to an equal amount in grain; for rations rather than feeds are dealt with in this instance, and different roughages were used in the two rations, a lower grade being used in the ration for Lot 2.

TABLE VII: Average daily production of each cow, 1908.

Name of cow	31 days before test		60 days of test		30 days after test	
	Milk (lbs.)	Fat (lbs)	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn, cotton-seed meal						
Miami Pride	25.65	1.082	23.66	1.064	22.93	1.072
Topsy May	19.35	1.130	17.55	1.062	17.10	1.043
Mantee Mahomet	20.56	.580	19.81	.580	19.60	.524
Teeny Gray 2nd	14.67	.889	14.31	.857	14 34	.853
Little May	17.48	.948	16.31	.992	15.71	.923
Average	19.54	.926	18.29	.897	17.93	.883
Lot 2. Ration during test: corn silage, corn stover, bran, corn, cotton-seed meal						
May's 2nd	21 25	1.158	18.80	1 067	18.00	1.013
Phillip's 4th	21.51	1.041	19 03	.935	17.25	.854
Grace Daw	24.82	.759	24.95	.783	26.68	.861
Fair Mahomet	21.18	.686	21 63	712	22 61	.695
May 2nd Pedro	12.45	.776	13.91	.874	14.01	.865
Bessie Nervilette	21.39	1.176	18.90	1.106	17.73	1.037
Average	20.43	.932	19.53	.913	19.38	.885
Difference	.89	.006	1.24	.016	1.35	.002

Table VII shows that Lot 2 gave slightly more milk and butterfat daily per cow than Lot 1, but this difference did not change with a change of ration. This shows that the two rations were practically equal in feeding value so far as milk and butterfat production is concerned. These results are shown more graphically in Figure 1. The scale to the left represents pounds of milk daily and that ot the right represents pounds of fat daily. The solid lines represent the production of Lot 1 and the broken lines that of Lot 2.

While the production of milk and fat is the important point to dairymen, the gain or loss in live weight should be taken into consideration. Table VIII shows that the gain in each lot was practically the same, being less than one-half pound per cow per day.

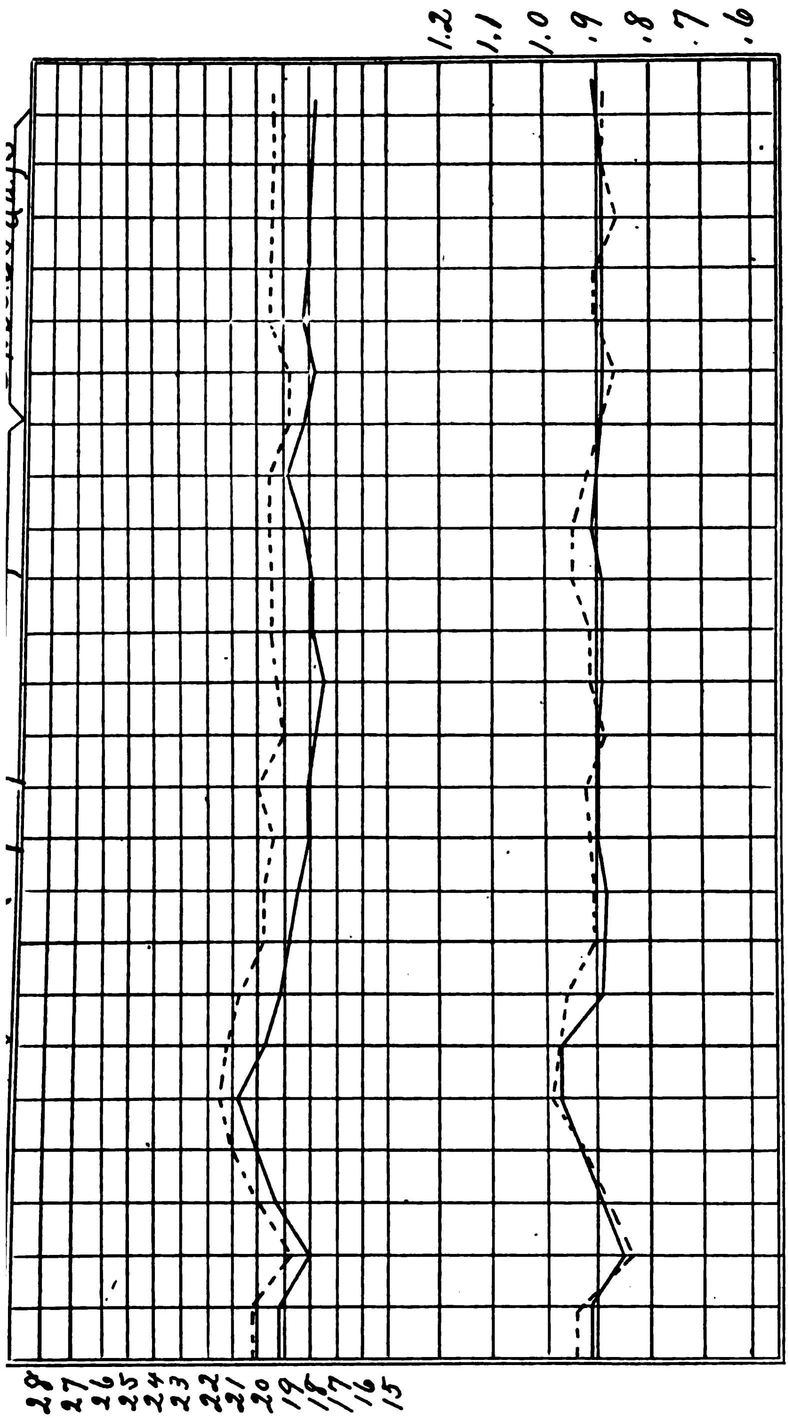

Figure 1.

TABLE VIII: Summary of weights, 1908.

Name of cow	Average weight at beginning of test (lbs.)	Average weight at end of test (lbs.)	Gain or loss (—) for 60 days (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn and cotton-seed meal			
Miami Pride	925	948	23
Topsy May	829	858	29
Mantee Mahomet	1,103	1 144	41
Teeny Gray 2nd	753	767	14
Little May	825	862	37
Average	887	915.8	28.8
Lot 2. Ration during test: corn silage, corn stover, bran, corn and cotton-seed meal			
May's 2nd	929	956	27
Phillip's 4th	968	998	30
Grace Daw	1,152	1,133	—19
Fair Mahomet	853	898	45
May 2nd Pedro	834	877	43
Bessie Nervilette	824	850	26
Average	926.6	952	25.3

Another method of measuring the relative efficiency of the two rations is to compare the amount of dry matter consumed per unit of product, milk or butterfat. This comparison is shown in Table IX, and indicates that the difference is very small.

TABLE IX: Amount of dry matter required to produce a unit of product, 1908.

Name of cow	Milk produced (lbs.)	Butterfat produced (lbs.)	Total dry matter consumed (lbs.)	Dry matter per 100 lbs. of milk (lbs.)	Dry matter per pound butterfat (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal					
Miami Pride	1,418.0	63.845	1,301.09	91.75	20.38
Topsy May	1,053.1	63.712	1,293.59	122 83	20.30
Mantee Mahomet	1,188.5	34.763	1,221.76	102.79	35.15
Teeny Gray 2nd	848.2	51.417	1,196.59	141.07	23.27
Little May	978.9	55.333	1,206.93	124.29	21.81
Average	1,097.3	53.814	1,243.99	113.36	23.23
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal					
May's 2nd	1,128.4	64.040	1,328.53	117.73	20.75
Phillip's 4th	1,141.8	56.096	1,267 40	111.00	22.59
Grace Daw	1,497.0	46.995	1,360.74	90.89	28.96
Fair Mahomet	1,297.9	42.654	1,278.98	98.54	29.99
May 2nd Pedro	834.5	52.816	1,202.28	144.07	22.76
Bessie Nervilette	1 134.0	66.335	1,264.75	111.47	19.07
Average	1 172.3	54.823	1 283.78	109.51	23.42

FINANCIAL STATEMENT

The average dairyman is interested in the relative efficiency of the two rations, because of the effect on the cost per unit of product. A financial statement is given in Table X; but it must be kept in mind that this statement is correct only when the prices given on page 128 are used. Any change in prices would affect the financial results.

TABLE X: Cost of feeds and value of product, 1908.

Name of cow	Cost of product				Value of product			
	Total cost of feed	Average daily cost of feed	Cost per 100 lbs. milk produced	Cost per pound butterfat produced	Butter-fat	Skim-milk	Total	Average daily value of product
Lot 1. Ration during test: corn silage, soybean hay, corn and cotton-seed meal								
Miami Pride	$ 9.77	$ .163	$ .689	$ .153	$ 15 96	$2.03	$17.99	$ .300
Topsy May	9 28	.155	.881	.146	15.93	1.48	17.41	.290
Mantee Mahomet	9.32	.165	.784	.268	8.69	1.73	10.42	.174
Teeny Gray 2nd	8.76	.146	1.033	.170	12.85	1.20	14.05	.234
Little May	8.79	.147	.898	.159	13.83	1.38	15.21	.254
Average	9.18	.155	.857	.179	13.45	1 56	15.01	.250
Lot 2. Ration during test: corn silage, corn stover, corn meal, bran and cotton-seed meal								
May's 2nd	$10.44	$ .174	$ .925	$ .163	$ 16.01	$1.60	$17.61	$ .294
Phillip's 4th	9.62	.160	.843	.172	14.02	1.63	15.65	.261
Grace Daw	10.53	.176	.703	.224	11.75	2.18	13 93	.232
Fair Mahomet	10.29	.172	.793	.241	10.66	1.88	12 54	.209
May 2nd Pedro	8.71	.145	1.044	.165	13.20	1.17	14.37	.240
Bessie Nervilette	9.57	.160	.844	.144	16.58	1.60	18.18	.303
Average	9.86	.164	.858	.185	13.70	1.68	15.38	.256

While profit is the practical test of the value of feeds, market conditions fluctuate to such an extent that no definite conclusions that will apply through a series of years can be drawn. This table shows that the cost of the product under the market prices which were applied was practically the same for both lots, although Lot 1 yielded the product at a slightly lower cost.

RESULTS OF THE SECOND TEST

Nine cows were used in this test, which was practically a repetition of the foregoing test. Lot 1 contained four cows, and Lot 2, five cows (See Table 2). The rations used were the same as those used in the previous test except that a change, as previously stated,

was made during the subsequent period, (See page 128). The test continued for 133 days—28 days preliminary, during which both lots were on the soybean ration, 77 days on the different rations, and 28 days subsequent to this period.

TABLE XI: Feed consumed during test, 1909.

Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal

Name of cow	Total pounds feed consumed				Average daily pounds feed consumed			
	Corn meal	Cotton-seed meal	Silage	Soybean hay	Corn meal	Cotton-seed meal	Silage	Soybean hay
Grace Daw	475.2	79 2	3,431	870	6.17	1.03	31.57	11.30
Bessie Nervilette..	475.2	79.2	2,596	594	6.17	1.03	33 72	7.71
May 2nd Pedro....	475.2	79.2	1,980	628	6.17	1.03	25.71	8.16
Teeny Gray 2nd...	422.4	70.4	2,311	634	5.49	.91	30.02	8.24
Average......	462.0	77.0	2,329	681.7	6.00	1.00	30.25	8.85

Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal

Name of cow	Total pounds feed consumed					Average daily pounds feed consumed				
	Bran	Corn meal	Cotton-seed meal	Silage	Stover	Bran	Corn meal	Cotton-seed meal	Silage	Corn stover
Lady Thorne 4th..	231.0	231.0	231.0	1,919	487.0	3.00	3.00	3.00	24.93	6.32
Fair Mahomet.....	231.0	231.0	231.0	2,399	440.0	3.00	3.00	3.00	31 15	5.72
Miami Pride......	231.0	231.0	231.0	2,623	511.0	3.00	3.00	3.00	34 07	6.64
Little May	205.3	205.3	205 3	1,775	564.0	2.67	2.67	2.67	23 06	7.33
Topsy May.......	231 0	231.0	231.0	2,619	420.0	3.00	3.00	3.00	34.02	5.64
Average.......	225 8	225.8	225.8	2,267.6	482.7	2.93	2.93	2.93	31.41	6.33

Table XI shows the amount of food consumed by each lot during the different periods. The silage consumed by Lot 1 exceeded the silage consumed by Lot 2 by 1 percent; this is the reverse of what took place in the first test. In both the first and second test, 37 percent more soybean hay was consumed than stover. As in the first test, the total amount of grain consumed was greater for Lot 2 by 25.6 percent, and these grains were the most expensive. As in the previous test, the total nutrients consumed was practically the same.

Table XII shows the amount of nutrients consumed daily by each cow. On the average, there was very little difference between the nutrients consumed by the two lots.

TABLE XII: Average daily pounds nutrients consumed, 1909

Name of cow	Protein	Crude fiber	Nitrogen-free extract	Ether extract
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal				
Grace Daw	3.314	5.386	15.254	.973
Bessie Nervilette	2.876	4.430	14.337	.883
May 2nd Pedro	2.716	3.951	12.806	.882
Teeny Gray 2nd	2.720	4.233	13.133	.825
Average	2.906	4.500	13.882	.876
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal				
Lady Thorne 4th	2.881	4.027	13.123	.860
Fair Mahomet	2.977	4.432	13.988	.896
Miami Pride	3.033	4.579	14.443	.916
Little May	2.685	4.108	12.705	.799
Topsy May	3.033	4.469	14.460	.917
Average	2.922	4.323	13.746	.878

Table XIII shows that there is slight difference in the average daily production of milk in favor of Lot 2; this continues until the subsequent period. There is a slight difference in the production of fat in favor of Lot 1; this difference remains practically constant throughout the entire period, showing that the two rations were almost equal in productive value, which agrees with the results in the first test.

TABLE XIII: Average daily production of each cow, 1909.

Name of cow	28 days before test		77 days of test		28 days after test	
	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal						
Grace Daw	35.08	1.070	28.50	.952	28.26	.927
Bessie Nervilette	21 66	1.225	19.59	1.140	17 34	.972
May 2nd Pedro	24.85	1.270	21.58	1.149	19.97	1.004
Teeny Gray 2nd	16.46	.968	14.10	.843	12.97	.749
Average	24.51	1.133	20.94	1.021	19.63	.913
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal						
Lady Thorne 4th	26.91	.800	22.21	.741	18.62	.642
Fair Mahomet	32.50	1.040	27.57	.914	26.40	.864
Miami Pride	29 14	1.275	22.89	1.043	18.59	.823
Little May	16.16	.885	13.80	.839	13.53	.788
Topsy May	26.58	1.422	21.36	1.265	18.92	1.078
Average	26.26	1.084	21.56	.960	19.21	.839
Difference	1.75	.049	.62	.061	.42	.074

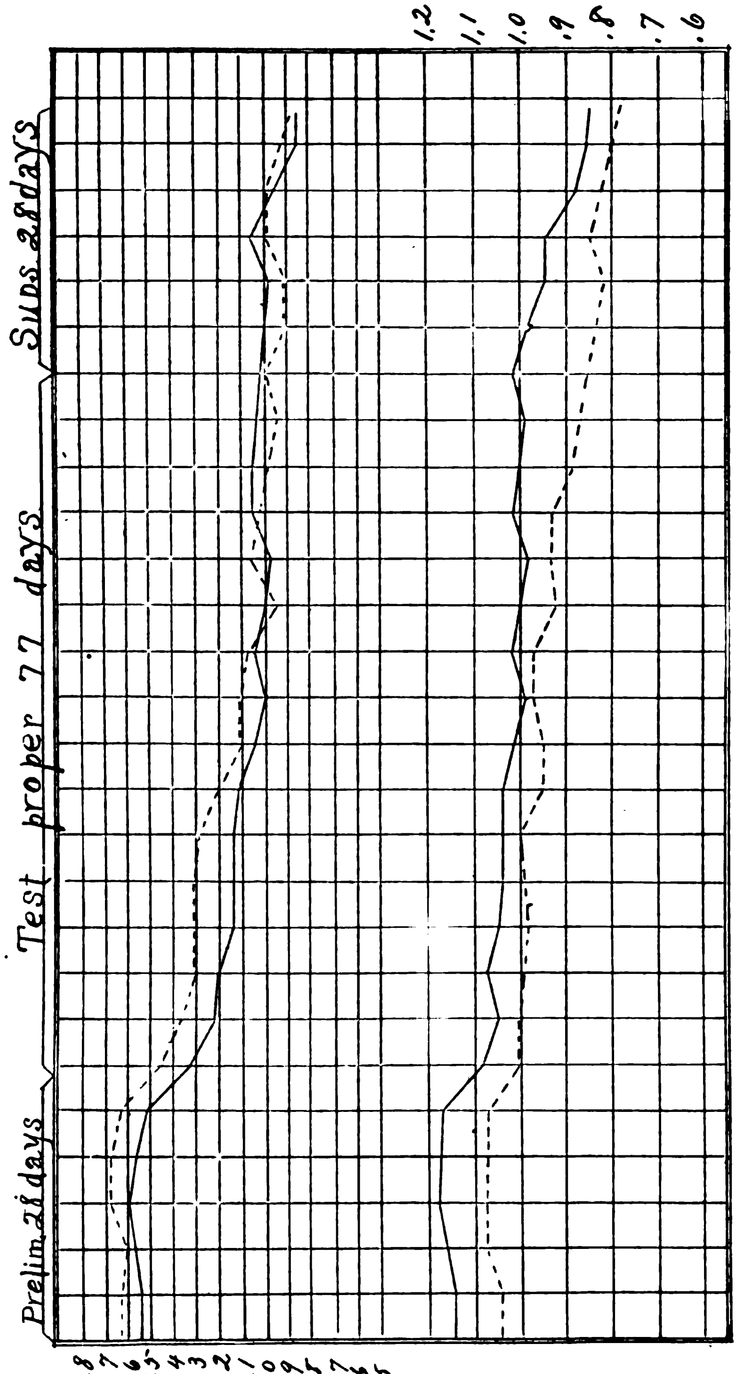
Prelim. 28 days
Test proper 77 days
Subs. 28 days
1.2
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Figure 2.

Fig. 2 shows graphically the production of the two lots in the test of 1909. The scale to the left represents pounds of milk daily, and the scale to the right represents pounds of fat daily. The upper solid line represents the average daily production of milk by Lot 1 and the lower solid line represents fat produced daily. The upper broken line represents the average pounds of milk produced daily by Lot 2 and the lower broken line represents the average pounds of butterfat produced daily.

TABLE XIV: Summary of weights, 1909.

Name of cow	Average weight at beginning of test (lbs.)	Average weight, at end of test (lbs.)	Gain or loss (−) (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal			
Grace Daw	1,139.0	1,155.0	16.0
Bessie Nervilette	845.0	862.0	17.0
May 2nd Pedro	842.0	833.0	−9.0
Teeny Gray 2nd	831.0	843.0	12.0
Average	914.2	923.2	9.0
Lot 2: Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal			
Lady Thorne 4th	988.0	1,011.0	23.0
Fair Mahomet	915.0	925.0	10.0
Miami Pride	1,015.0	1,015.0	0.0
Little May	821.0	863.0	42.0
Topsy May	877.0	906.0	29.0
Average	923.2	944.0	20.8

Table XIV shows the summary of the weights of the cows. The value of a ration can not be determined by considering the production of milk only, but the gain or loss in body weight should also be taken into account. The average gain for Lot 1 was 9 lbs. (1-6 pound daily) and that for Lot 2 was 20.8 lbs. (less than ⅓ lb. daily). In this test the grain ration produced the greater gain. Neither lot gained as much as in the first test, though the latter period extended for 17 days longer than the former.

Table XV shows the total amount of products yielded, the total amount of dry matter consumed, and the amount of dry matter required per unit of product. It appears that 5 percent more dry matter was required to produce a unit of product with the grain ration than with the soybean ration. This is a greater difference than in the previous test, but it is a small difference, and it means that the two rations were practically equally efficient.

TABLE XV: Amount of dry matter required to produce a unit of product, 1909.

Name of cow	Milk produced (lbs.)	Butterfat produced (lbs.)	Total dry matter consumed (lbs.)	Dry matter per 100 lbs. of milk (lbs.)	Dry matter per pound butterfat (lbs.)
Lot 1. Ration during test: corn silage, soybean hay, corn meal and cotton-seed meal					
Grace Daw	2,194.6	73.366	2,021.68	92.12	27.42
Bessie Nervilette	1,508.5	87..92	1,814 48	120.28	20.67
May 2nd Pe?ro	1,661.9	88.435	1,642.81	98 86	18.58
Teeny Gray 2nd	1 085.4	64.908	1,693.31	156.00	26.09
Average	1,612.6	78.618	1,793 07	111.19	22.81
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal and cotton-seed meal					
Lady Thorne 4th	1,710.3	57.068	1,694.21	99.05	29.69
Fair Mahomet	2,122.6	70.409	1,806.71	85.11	25.66
Miami Pride	1,762.9	80 290	1,860.31	105.52	23.17
Little May	1,062.4	64.600	1,647.19	155.04	25.50
Topsy May	1,645.0.	97.417	1,853.29	122.66	19.02
Average	1,660.6	73.957	1,772.34	106.72	23.96

FINANCIAL STATEMENT

Table XVI gives a financial statement of the results of the test. The difference in the daily cost of feed per cow was less than 1 cent in favor of the soybean ration. The difference in the cost of 100 pounds of milk was a little over 1 cent. The difference in the cost of butterfat was 2.9 cents per pound in favor of the soybean ration.

TABLE XVI. Cost of feeds and value of product, 1909

Name of cow	Cost of product				Value of product			
	Total cost of feed	Average daily cost of feed	Cost per 100 lbs. milk produced	Cost per lb. butterfat produced	Butter fat	Skim-milk	Total	Average daily value of product
Lot 1. Ration during test: corn silage, soybean hay, corn meal, cotton-seed meal								
Grace Daw	$13.07	$ .170	$ .595	$ .178	$18.33	$3.18	$21.51	$ .279
Bessie Nervilette	12.22	.159	.810	.139	21.95	2.13	24 08	.313
May 2nd Pedro	11.42	.148	.687	.129	22 11	2.36	24.47	.318
Teeny Gray 2nd	11.29	.147	1.040	.174	16.23	1.53	17.76	.231
Average	12.00	.156	.783	.155	19.65	2.30	21.95	.285
Lot 2. Ration during test: corn silage, corn stover, bran, corn meal, cotton-seed meal								
Lady Thorne 4th	$ 12.40	$ .161	$ .725	$ .217	$14.27	$2.48	$16.75	$ .218
Fair Mahomet	13.03	.169	.614	.185	17.60	3.08	20.68	.269
Miami Pride	13.50	.175	.766	.168	20 07	2.52	22.59	.293
Little May	11.38	.148	1.071	.183	15.59	1.50	17.09	.222
Topsy May	13.32	.173	.810	.168	24.35	2.32	26.67	.346
Average	12.72	.165	.797	.184	18.37	2.38	20.75	.269

A careful study of these two tests shows that they agree very closely in the results obtained, showing that a large share of the protein can be supplied in soybean hay instead of concentrates, with equal efficiency.

PART II.

PLAN

In view of the results secured through the use of soybean hay as a protein carrier, it was decided to conduct a similar experiment using alfalfa hay as the source of home-grown protein. Alfalfa is destined to become a very important crop in certain sections of Ohio, notably, the western sections. Its production will be attended with greater difficulty in the eastern section, because of the greater lack of lime in the soil. Its enormous yields and high protein content make it especially desirable for dairy purposes. It is possible to combine alfalfa with home-grown feeds in such manner as to secure a balanced ration for reasonably high milk production. If it is possible to get as good results from such rations as from rations containing high priced grain by-products, the cost of milk production will be reduced.*

Each lot consisted of 3 Jerseys and 3 Holsteins. Their ages varied from 2 years, 3 months to 8 years. On the whole the two lots appeared to be exceptionally well balanced; and it is believed that the results should be comparable from this standpoint.

TABLE XVII. Division of cows.

Name of cow	Breed	Age at beginning of test (yrs.)—(mo.)	Date of last calf	Date bred
Lot 1				
La'y May Pedro......	Jersey	2—6	Nov. 5, 1909	Apr. 3, 1910
Little May	"	8—5	Sept. 26, 1909	Jan. 13, 1910
Fair Mahomet........	Holstein	4—9	Nov. 28, 1909	Apr. 14, 1910
Mantee 3rd	"	2—4	Nov 2, 1909	Mar 29, 1910
Lady Gre ta..........	"	2—6	Dec. 20, 1909	Mar 24, 1810
Bessie Lambert.......	Jersey	2—3	Jan. 17, 1910	Apr. 29, 1910
Average...........	... .	3—10	Nov 21, 1900	Mar 24, 1910
Lot 2				
Bessie Nervilette.....	Jersey	6—9	Dec. 3, 1909	Apr 15, 1910
Grace Daw 4th	Holstein	2—5	Nov 13, 1909	Apr. 5, 1910
Teeny Gray 2nd......	Jersey	4—11	Oct. 29, 1909	May 25, 1910
Lady Thorne 4th......	Holstein	4—11	Aug 11, 1909	Nov 11, 1909
F. ir Mahomet 1st....	"	2—6	Dec. 26, 1909	May 5, 1910
Lucy May............	Jersey	2—4	Jan. 8, 1910	Apr. 17, 1910
Average............	....	4—0	Nov. 15, 1909	Mar. 29, 1910

*For information about soybean culture and yields see Circulars 78, 132 and Bul. 237 of the O. A. E. S

The ration supplied Lot 1 consisted of corn meal, corn silage, and alfalfa hay; and that supplied Lot 2 consisted of corn meal, wheat bran, cotton-seed meal, corn silage and corn stover, the nutritive ratio being practically the same. The test proper lasted for 56 days during which time the two lots were on the rations mentioned above. In order to determine their production when on like rations, both lots were fed for a preliminary period of four weeks on the ration prescribed for Lot 1. For four weeks subsequent to the test proper, both lots were fed the ration prescribed for Lot 2.

FEED CONSUMED

TABLE XVIII. Average feed consumed daily during 56 days test

Name of cow	Corn meal (Lbs.)			Corn silage (Lbs.)	Alfalfa hay (Lbs.)
Lot 1					
Lady May Pedro	5.045			27 067	9 978
Little May	6.973			27.785	11.210
Fair Mahomet	6.045			30.058	13 330
Mantee 3rd	6.045			30 152	13 446
Lady Gretta	6.000			27 031	12.170
Bessie Lambert	5.000			23.000	9.473
Average	5.851			27.848	11.601
Lot 2	Bran	Corn meal	Cotton-seed meal	Corn silage	Corn stover
Bessie Nervilette	3 563	3 563	3 563	30.625	6.723
Grace Daw 4th	3 000	3 000	3.000	30 357	6.652
Teeny Gray 2nd	3.568	3.568	3 568	30.571	7.138
Lady Thorne 4th	3 000	3.000	3.000	29 393	6.839
Fair Mahomet 1st	3.000	3 000	3.000	30 000	4.183
Lucy May	2.500	2.500	2.500	25 000	2.647
Average	3.105	3.105	3 105	29.324	5.614

Table XVIII shows the average daily feed consumed during the test proper. It will be noted that the average daily grain ration received by Lot 1 was 5.85 pounds and that by Lot 2, 9.31 pounds. This shows over one-third more grain for Lot 2, while Lot 1 consumed twice as much alfalfa hay as Lot 2 consumed stover. There was not a great difference in the total amount of nutrients consumed. The exact figures are shown in the following table.

TABLE XIX. Compositions of average daily rations.

Lbs.	Feed	Dry matter (lbs.)	Protein (lbs.)	Crude fiber (lbs.)	Nitrogen free extract (lbs.)	Ether extract (lbs.)
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay.						
5.9	Corn meal	4.81	.52	.10	3.88	.22
27.8	Corn silage	5.67	.39	1.70	3.11	.13
11.6	Alfalfa hay	10.19	1.60	4.00	3.57	.14
	Total	20.67	2.51	5.80	10.56	.49
Lot 2. Ration during test: Bran, corn meal, cotton-seed meal, corn silage, stover						
3.1	Wheat bran	2.72	.48	.14	1.87	.12
3.1	Corn meal	2.53	.27	.05	2.04	.12
3.1	Cotton-seed meal	2.80	1.25	.28	.85	.21
29.3	Corn silage	5.97	.41	1.79	3.27	.14
5.6	Corn stover	4.27	.30	1.57	2.08	.07
	Total	18.29	2.71	3.83	10.11	.66

Lot 1 consumed less protein and more crude fiber than Lot 2; and from this one would naturally conclude that Lot 1 should produce a little less milk, unless the protein supply in ration 1 was entirely sufficient for their needs, in which case a slight excess was used in ration 2.

PRODUCT RETURNED

TABLE XX. Average daily production of milk and butterfat.

Name of cow	28 days before test		56 days of test		28 days after test	
	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)	Milk (lbs.)	Fat (lbs.)
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay						
Lady May Pedro	12.9	.74	11.20	.65	10.8	.64
Little May	21.4	1.22	18.20	1.03	16.5	.93
Fair Mahomet	31.8	1.08	32.15	1.03	33.6	1.02
Mantee 3rd	26.7	.87	25.22	.81	22.9	.74
Lady Gretta	30.4	1.2	30.64	.95	29.0	.84
Bessie Lambert	16.8	.84	14.57	.78	13.3	.77
Average	23.4	.96	22.04	.87	21.0	.82
Lot 2. Ration during test: Corn, bran, cotton-seed meal, [illegible] silage, stover						
Bessie Nervilette	24.3	1.36	20.48	1.1[illegible]	18.2	1.02
Grace Daw 4th	25.1	.88	23.68	[illegible]	23.3	.71
Teeny Gray 2nd	20.1	1.21	19.12	1.20	16.7	1.03
Lady Thorne 4th	25.0	.74	24.37	.74	27.3	.81
Fair Mahomet 1st	23.1	.77	21.82	.68	18.1	.55
Lucy May	15.4	.90	13.77	.82	11.8	.71
Average	22.1	.98	20.54	.90	19.2	.8[illegible]

Table XX shows the amount of milk and fat produced daily by the individual cows and the average. From this table we observe that Lot 1 produced slightly more milk than Lot 2, while Lot 2 produced slightly more butterfat than Lot 1. This difference in fat is undoubtedly due to the difference in the original percentage of butterfat between the two lots. While there is a difference between the two lots, this difference remains quite constant throughout the three periods, indicating that the two rations were practically equal in efficiency. Though there was little difference in the production of milk and butterfat, there seems to have been more difference in the weight of the animals. It is interesting to note that the lot producing the largest amount of butterfat gained the least in weight.

TABLE XXI. Summary of weights.

Name of cow	Average weight at beginning of test (lbs.)	Average weight at end of test (lbs.)	Loss or gain in weight during test (lbs.)
Lot 1. Ration during test: Corn meal, corn silage and alfalfa hay.			
Lady May Pedro	791.0	855.0	64.0
Little May	811.0	812.0	31.0
Fair Mahomet	780.0	784.0	4.0
Mantee 3rd	872.0	934.0	62.0
Lady Gretta	938.0	960.0	22.0
Bessie Lambert	675.0	711.0	36.0
Average	844.5	881.0	36.5
Lot 2. Ration during test: Bran, corn, cotton-seed meal, corn silage and stover.			
Bessie Nervilette	884.0	882.0	—2.0
Grace Daw 4th	954.0	968.0	14.0
Teeny Gray 2nd	837.0	840.0	3.0
Lady Thorne 4th	978.0	991.0	13.0
Fair Mahomet 1st	1,008.0	1,003.0	—5.0
Lucy May	757.0	740.0	—17.0
Average	903.0	904.0	1.0

The table shows that Lot 1 gained an average of 36.5 pounds in the 56 days, while Lot 2 gained 1 pound. Every cow gained on the alfalfa ration while 3 gained and 3 lost on the other ration. (Average of 3 days weights.) This would indicate that a little more carbohydrates and fat were given than were required for milk production. This partly explains the difference in the amount of dry matter required to produce a given amount of milk and fat, as shown in the next table. It is also partly explained by the fact that Lot 1 received more crude fiber than did Lot 2.

TABLE XXII. Comparative production based on dry matter

Name of cow	Milk produced (lbs.)	Butterfat produced (lbs.)	Total dry matter consumed (lbs.)	Dry matter per 100 lbs. milk (lbs.)	Dry matter per lb butterfat (lbs.)	Average daily dry matter consumed (lbs.)
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay.						
Lady May Pedro	628.1	36.4	1,030.3	164.3	28.3	18.4
Little May	1,019.2	57 8	1,187.2	116 5	20 5	21 2
Fair Mahomet	1,800.6	57.7	1,275.1	70.8	22.1	22.8
Mantee 3rd	1,412.4	45.4	1,281.8	90.8	28.3	22 9
Lady Gretta	1,715.8	53.1	1,181.4	68 9	22 2	21.1
Bessie Lambert	812.8	43.6	979.8	120.6	22.5	17.5
Average	1,231.3	49.0	1,155.9	105.3	24.0	20.6
Lot 2. Ration during test: Bran, corn, cotton-seed meal, corn silage, corn stover						
Bessie Nervilette	1,147.3	66.0	1,155.3	100.7	17.5	20.6
Grace Daw 4th	1,326.6	46.1	1,030.3	77.6	22.4	18.4
Teeny Gray 2nd	1,071.1	67.4	1,172.0	109.4	17 4	20.9
Lady Thorne 4th	1,365.2	41.6	1,043.2	76.4	25.0	18.6
Fair Mahomet 1st	1,222.0	38.1	957.9	78.4	25 2	17.1
Lucy May	771.6	46.0	762.4	98.8	16.6	13.6
Average	1,150.6	50.9	1,020.2	90.2	20.7	18.2

The above table shows that Lot 1 consumed 16.6 percent more dry matter per 100 pounds of milk, and 19.3 percent more per pound butterfat. The economy of a ration depends on its cost as well as on its efficiency. In the following table the costs are set forth; but, these costs apply only when the prices given on page 128 are used.

TABLE XXIII. Cost of product

Name of cow	Total cost of feed	Average daily cost of feed	Cost to produce 100 lbs. of milk	Cost to produce 1 lb. of butterfat
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay.				
Lady May Pedro	$ 7 90	$ .14	$1.26	$ .22
Little May	9.38	.17	.92	.16
Fair Mahomet	9.64	.17	.54	.17
Mantee 3rd	9.68	.17	.69	.21
Lady Gretta	9.04	.16	.53	.17
Bessie Lambert	7.55	.13	.93	.17
Average	8.86	.16	.81	.18
Lot 2. Ration during test: Bran, corn meal, cotton-seed meal, corn silage, stover.				
Bessie Nervilette	$10.71	$ .19	$ .93	$ .16
Grace Daw 4th	9.51	.17	.72	.21
Teeny Gray 2nd	10.74	.19	1.00	.16
Lady Thorne 4th	9.40	.17	.69	.23
Fair Mahomet 1st	9 20	.16	.75	.24
Lucy May	7.57	.14	.98	.16
Average	9.53	.17	.85	.19

It will be noted that the average difference in cost per 100 pounds of milk was 4 cents, and per pound butterfat was 1 cent in favor of Lot 1 on the alfalfa ration. It is interesting to note from the following table that the cost of the feed equaled 61 percent of the value of the product in Lot 1 and 68 percent in Lot 2, leaving 39 and 32 percent to be accounted for by labor, taxes, depreciation, interest, profit, insurance, etc.

TABLE XXIV. Value of product on butter basis.

Name of cow	Value of butterfat	Value of Skim milk	Total value of product	Average daily value of product
Lot 1. Ration during test: Corn meal, corn silage, alfalfa hay				
Lady May Pedro	$ 9.10	$ .89	$ 9.99	$ .18
Little May	14.45	1.44	15.89	.28
Fair Mahomet	14.43	2.61	17 04	.30
Mantee 3rd	11.34	2.05	13.39	.24
Lady Gretta	13 28	2.49	15.77	.28
Bessie Lambert	10 90	1.15	12.05	.22
Average	12.25	1.77	14.02	.25
Lot 2. Ration during test: Corn, bran, cotton-seed meal, corn silage, stover.				
Bessie Nervilette	$16.50	$1 62	$18.12	$.32
Grace Daw 4th	11.52	1.92	13.44	.24
Teeny Gray 2nd	16.85	1 51	18.36	.33
Lady Thorne 4th	10 40	1.99	12.39	.22
Fair Mahomet 1st	9.51	1.78	11.29	.20
Lucy May	11.49	1.09	12.58	.22
Average	12.71	1.65	14.36	.26

CONCLUSIONS

The above considerations show that alfalfa as well as soybeans can replace much of the high priced protein concentrates. Other legumes will answer the same purpose in a lesser degree. Clover is especially valuable in this respect, though not as good results should be expected per ton as with the soybean or alfalfa hay.

From the above it is evident that the extensive use of milling by-products or other commercial feeds is not necessary in milk production where legumes can be grown well. However, it often proves profitable to use such feeds and unless the use of home-grown feeds will yield as great a profit, all things considered, the commercial feeds should be used.

There are other factors than simply the efficiency of the ration which should be taken into consideration in figuring profits. Some of the factors are: Adaptability of the farm for growing the feeds desired; distance crops or feeds must be hauled to or from the market; the suitability of legumes for desired rotations; relative

value of fertilizing constituents of feeds purchased or produced; effect of legumes on the soil; the investment required in the purchase of grains or mill feeds; other and possibly more economical means of handling the soybean plant, and the consideration of market conditions.

The investment required when one depends on grains and mill feeds for protein is, perhaps, of minor importance. It is true, however, that on many occasions money with which to purchase feeds is not available, and also that the use of money during the time the feed is being consumed is of sufficient importance to warrant consideration.

The most economical way to handle the soybean plant is to many an unsettled question. On account of its nature of growth, the stem of the plant is quite woody and the cattle do not eat the stems readily. The time and manner of harvesting will control this point to a considerable extent. The practice of putting soybeans into the silo with corn silage is growing in some places, though it makes a strongly flavored silage. This plan is, perhaps, most popular at present; and on account of the difficulty in curing it for hay seems to be the best method of handling the soybean plant. However, the use of the soybean in the form of hay is altogether practical and is preferred by some.

An intimate knowledge of all local conditions, which is possible only to the man on the ground, is necessary if the most economical selections of feeds are to be made.

ACKNOWLEDGMENTS

Special recognition is due Mr. B. E. Carmichael, Chief of the Department of Animal Husbandry, for his valuable assistance in planning and directing much of the work reported in this publication, and to Mr. C. C. Hayden, present head of the Department of Dairy Husbandry, who assisted in the final arrangement of material.

CORRECTIONS TO CIRCULAR 136

On page 124 of Circular 136, directions are given for mixing fly repellants. It seems that two errors have been made. In formula 1, not over one-half pint of the acid should be used. This formula is hardly advisable since there is such great variation in the purity of carbolic acid designated as "crude."

In formula 2, the word *parts* should read *pints*. For formula 1, substitute 100 parts fish oil, 50 parts oil of tar (not tar) and 1 part of crude carbolic acid.

SUBSTITUTES FOR CORN IN RATIONS FOR FATTENING SWINE

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JANUARY, 1914

BULLETIN 268

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

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BULLETIN

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FORAGE CROPS: ANNUAL GRASSES AND ROOTS

C. G. WILLIAMS AND F. A. WELTON

The word "forage" is used in this bulletin to include those farm crops which are grown for the feeding of livestock and are fed as a whole, either green or dry. For instance: Corn, when it is husked and fed separately as grain and stover, is not considered a forage crop; but when the whole plant is fed as one feed, whether green, dry, or as silage, it is classed as a forage crop.

Our forage crops are found in three principal groups: Grasses, legumes and roots. This bulletin will treat the more valuable annual grasses and roots which have been tested at this Station. The perennial grasses are treated in Bulletin 225; soybeans and cowpeas in Bulletin 237 and, in a future publication, the clovers and some other legumes will be discussed.

In forage crops, as well as in grain crops, corn may properly head the list.

VARIETY TESTS OF CORN FOR THE SILO

For the past ten years the Ohio Station has been testing a number of different varieties of corn for use as silage. It has had difficulty, some seasons, in securing some of the varieties with which work was started and accordingly is able to report work with eight varieties for 5 consecutive seasons only.

TABLE I. Varieties of corn for the silo

Variety	Tons of corn per acre						Percent				Pounds per acre				
	1913	1912	1911	1910	1909	5-year av.	Protein	Crude fiber	Nitrogen free extract	Fat	Protein	Crude fiber	Nitrogen free extract	Fat	Total nutrients
Blue Ridge—Virginia	12.55	20.71	15.52	7.78	15.82	14.48	1.96	6.20	16.23	.50	567.6	1795.5	4700.2	144.8	7389.1
Hickory King—Virginia	12.34	18.43	13.70	7.15	16.56	13.64	2.00	5.50	15.10	.44	545.6	1500.4	4119.3	120.0	6435.3
Pike Co. White—Ohio (U. S. 77)	12.28	16.26	15.85	7.13	12.61	12.83	1.82	5.07	15.56	.39	467.0	1301.0	3992.7	100.0	5985.7
Boone Co. White—Md., (U. S. 119)	12.43	16.26	15.74	6.83	13.43	12.94	2.07	5.78	16.29	.46	535.7	1495.8	4215.8	119.0	6515.0
Boone Co. White—Tenn., (U. S. 138)	12.96	18.14	15.39	6.85	16.17	13.90	1.89	5.65	14.03	.34	525.4	1570.7	3900.3	94.5	6209.0
Boone Co. White—Ohio	10.88	16.98	15.65	8.47	13.01	13.00	2.06	5.73	16.43	.50	535.6	1489.8	4271.8	130.0	6589.7
Darke Co. Mammoth—Ohio	7.26	15.04	13.87	4.86	14.04	11.01	2.28	5.47	18.75	.55	502.0	1204.5	4128.7	121.1	6107.7
Leaming—Ohio	8.43	11.48	12.22	5.09	10.46	9.54	2.43	6.40	20.34	.69	463.6	1221.1	3880.8	131.7	5861.8

Of the varieties reported upon, the Blue Ridge comes from old Virginia. It is a white dent corn with a white cob and is grown quite extensively by the dairymen of northeastern Ohio for silage uses.

The Hickory King also comes from Virginia, though it is grown quite extensively further south as a field corn.

The Pike County White (U. S. 77) is grown extensively in Pike County, Ohio, where it is known as "Woodburn's White."

Three strains of the Boone County White have been used. Two of them have been secured each year through the U. S. Department of Agriculture; one from Maryland (U. S. 119), the other from Tennessee (U. S. 138). The third strain has been secured new each year from southern Ohio.

The Darke County Mammoth is a popular variety of yellow dent field corn from Darke County, Ohio. It is considerably earlier than the above mentioned varieties and usually matures at Wooster.

The Leaming used in this test is an early strain from the son of the originator of this variety in Clinton County, Ohio.

The yields are given in tons of green corn as cut and weighed into the silo. There is no very marked variation in the maturity of the different varieties save in the case of the last two. The Darke County Mammoth and the Leaming being earlier varieties naturally carried less water than the others and their weight per acre is much lower.

For four of the five seasons reported, each variety was sampled the day it was cut and put in the silo and an analysis made by the Department of Chemistry. The method of sampling was to choose a number of representative plants of each variety. These plants were separated into fodder, grain and cob and each part was weighed and analyzed by itself. It is believed that the nutrients can be determined with greater accuracy in this way than by sampling the chopped corn at random. The average analyses of the different varieties for the several seasons appear in the columns giving the percentage composition. The pounds per acre of the different nutrients, as well as the total nutrients per acre, are computed from the 5-year average yield per acre and the percentage composition.

It will be noted that the varieties which might be classed as "field" corn (The Darke Mammoth and the Leaming), i. e., varieties adapted to the growing of grain because they may be expected to come to complete maturity, do not furnish as large an amount of nutrients per acre as the larger and somewhat later varieties. While a ton of this field corn silage will carry much more nutrients

than a ton of the larger, or so-called "silage" corn, an *acre* of it will furnish less nutrients. Attention should be called to the fact that considerably more water will have to be handled with the larger, or silage corn.

The Station does not recommend any particular variety or type of corn for the silo. It endeavors to report its findings impartially, realizing that the needs of individual dairymen differ. In intensive dairying, where it is a problem to secure enough roughage, the silage corn will likely prove more satisfactory. In the corn belt sections where the problem is to take care of the corn crop, the field corn will doubtless be more satisfactory. Silage made from the latter will not call for the purchase of as much concentrates to feed with it as the former.

While the above figures show more nutrients per acre from the later varieties, the mistake should not be made that mere lateness and immaturity are in themselves advantageous. It should be stated that the closer any variety approaches maturity the more nutrients *that variety* will carry. Accordingly the silage varieties should be planted as early as is safe and be left to come as close to maturity as possible. It is undoubtedly possible to go to extremes in the use of large and late varieties of corn for the silo, though it would seem that one might wisely grow varieties somewhat larger and later than he would feel safe in growing for grain only.

Two varieties of corn have been grown in this silage test for the full period of 10 years. One of them, the Leaming, of the field corn type; the other, the Blue Ridge, of the silage type. The latter was not known under the name of Blue Ridge at the beginning of this test, though it has always been secured from the same source and is the same corn.

The yields per acre are as follows:

TABLE II. The Leaming vs. the Blue Ridge

Variety	Tons of corn per acre										10-yr. av.
	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	
Blue Ridge.	12.55	20.71	15.52	7.78	15.82	12.80	15.42	15.25	15.25	15.86	14.79
Leaming...	8.43	11.48	12.22	5.09	10.46	7.30	10.55	10.57	11.60	16.45	10.41

The large yield of Leaming corn for 1904 was due to the fact that the Leaming used that year was a late western strain. It would, perhaps, be fairer not to average it in, as for the Ohio Station conditions it would rank with the silage, rather than with the field type. The 9-year average of the Leaming is 9.74 tons per acre.

In this variety test the corn was planted in hills in order that a perfect stand might be secured by thick planting, then thinned to a uniform stand when the corn was 6 to 8 inches high. In field work the Station drills its silage corn.

Fig. 1. Harvesting silage corn.

THICKNESS OF PLANTING CORN FOR THE SILO

This Station has been conducting experiments the past 5 years to determine if possible the proper distance apart to drop kernels in drilling corn for the silo. Four different distances have been tested, viz., 4, 6, 10 and 12 inches. A one-horse corn drill with brush feed has been used throughout the test and quite uniform dropping has been secured. The results of this test are given in Table III.

It will be noted that the differences in yield of corn per acre vary widely with the season. In 1909 and 1912 the 4-inch drilling led by a wide margin, while in 1911 and 1913 it was a little behind the 6-inch, and but slightly ahead of the 10-inch. In four of the 5 years the 12-inch planting has given the lowest yield of all.

It is of interest to compare the amount of rainfall for the months of June, July and August for the 5 seasons. It is apparent that it is during the seasons of excessive rainfall (1909 and 1912) that the 4-inch plantings make the large yields. In seasons when the rainfall is short or moderate the lead over the 12-inch planting is less than 1 ton per acre on the average. In so far as tons per acre are concerned the 5-year average yield drops quite regularly from the 4-inch to the 12-inch planting.

TABLE III. Thickness of planting corn for the silo. Variety: Blue Ridge

Kernels dropped every:	Tons of corn per acre						Average percent of				Pounds per acre				
	1913	1912	1911	1910	1909	5-yr. av.	Protein	Crude fiber	Nitrogen free extract	Fat	Protein	Crude fiber	Nitrogen free extract	Fat	Total nutrients
4 inches	13.47	21.25	14.88	9.57	19.53	15.74	1.58	7.03	15.11	.32	497.4	2213.0	4756.6	100.7	7693.6
6 inches	13.87	19.68	15.10	9.18	13.53	14.27	1.48	5.73	12.28	.27	422.4	1635.3	3504.7	77.1	5735.9
10 inches	13.18	17.20	14.68	8.50	14.11	13.53	1.71	5.78	13.47	.34	462.7	1564.1	3645.0	92.0	5878.8
12 inches	12.73	16.17	13.78	8.53	13.15	12.87	1.80	5.98	13.00	.31	463.3	1539.3	3346.2	79.8	5528.3

Comparative rainfall

	1913	1912	1911	1910	1909
June..........	0.97	2.21	3.78	2.57	6.44
July..........	4.07	7.46	3.36	1.12	4.05
August........	4.75	7.32	5.19	0.95	5.21
Total.........	9.79	16.99	12.33	4.64	15.70

As in the variety tests, chemical analyses have been made of each lot of corn for 4 of the 5 seasons. The average percentage of nutrients is indicated in the above table and the total pounds of nutrients per acre, based upon these percentages and the 5-year average yield of corn. The thickest planting—the 4-inch—leads in total nutrients, with the 10-inch second, the 6-inch third and the 12-inch fourth.

While these figures favor the 4-inch planting, there is one very serious disadvantage in this very thick planting which should be mentioned, viz., the plants do not stand up well. They are so slender that they lodge badly, thus making it difficult, both to cut the corn, even with a harvester, and to handle the bundles after they are cut. It is quite probable that, one year with another, 10-inch planting will prove most satisfactory.

This Station has not gathered any data upon the use of corn as a dry forage. The data furnished in Table III should, however, be applicable. Since the finer stalks will be consumed more closely than the coarser, it would doubtless be an advantage to plant corn thicker for dry feeding than for silage.

SORGHUMS

Among the annual forage grasses, sorghum probably ranks next to corn. Three types are usually recognized: Saccharine, non-saccharine and broom-corn.

On account of the dryness of its stems, broom-corn is of little or no value as a forage plant. It is grown almost exclusively for the production of seed and brush—a trade term for the material from which brooms are made—and consequently will not be discussed in this bulletin.

Saccharine sorghum is characterized by an abundance of sweet juice in the stalks of the plants. Formerly it was grown chiefly for the production of syrup but now it is utilized largely as forage, it being the best of all the sorghums for that purpose. Agriculturally, the term "sorghum" is often restricted to this division alone.

The stalks of non-saccharine sorghum possess a small amount of juice and, while sweet in some, in other varieties it is more or less sour.

The members of this division are grown chiefly for grain, and for that purpose they are of great value in semi-arid regions where the rainfall is not sufficient for the proper development of corn; but in humid climates, like that of Ohio, they are of minor value for the production of grain and are utilized to a limited extent only as forage.

For the past two years cane has been included in the Station's variety silage test. That it is hardly equal to corn in the production of silage under Ohio conditions is shown by Table IV, only two varieties—Darke County Mammoth and Leaming—falling below it in yield. The relatively high yields for 1912 may be attributed to excessive rainfall and to fertile soil, the test that year being conducted on an alfalfa sod.

TABLE IV Corn vs. cane silage.

Variety	Tons per acre		
	1912	1913	2-year average
Blue Ridge—Virginia	20.71	12.55	16.63
Hickory King—Virginia	18.43	12.34	15.38
Pike County White—O. (U. S. 77)	16.26	12.28	14.27
Boone County White—Md. (U. S. 119)	16.26	12.43	14.34
Boone County White—Tenn. (U. S. 138)	18.14	12.96	15.55
Boone County White—O,	16.98	10.88	13.93
Darke County Mammoth—O	15.04	7.26	11.15
Leaming—O	11.48	8.43	9.95
Cane	13.91	11.95	12.93

From time to time, for the past 13 years, a few of the older and more common varieties of sorghum, both saccharine and non-saccharine, have been grown on the Station farm, and from the yields of green forage, which are tabulated in Table V, it is possible to formulate some idea as to their relative value when grown under Ohio conditions.

TABLE V. Sorghum: Tons of green forage per acre.

Year	Variety					
	Saccharine		Non-saccharine			
			Kafir		Durra	
	Amber	Orange	Red	White	Yellow milo	White
1901	11.7	....	9.7	10.7	7.6	...
1902	13.2	....	10.4	10.9	4.9	5.8
1903	8.3	12.7	....	....	8.9	3.9
1905	13.4	17.2	10.1	12.8	...	...
1911	16.2	....	....	12.1	8.3	...
1912	6.2	10.7	5.9	6.9	4.9	..
1913	11.9	15.2	9.8	10.6	7.9	..
Average	11.6	13.9	9.2	10.7	7.1	4.8

Though there are several varieties of saccharine sorghum, only two—Amber and Orange—have been grown at Wooster.

Amber: On the Station farm, Amber attains a height of 7 to 10 et; has a moderate number of leaves and matures in ample time r the production of forage of good quality. The seed head or ınicle is black and more or less open. (Fig. 2.)

Orange: As compared with Amber the Orange is taller, ›arser, more leafy, later in maturity and in those years in which ɔth have been grown, the yield : Orange has exceeded that of .mber—the excess ranging from .5 to 4.5 tons per acre. The ɔarseness of the stalk renders : more difficult to cure and ence less desirable than Amber s cured forage. The seed head ›r panicle is more compact and ‹s it approaches maturity it akes on an orange color, hence he variety name. The greatest ısefulness of this variety in Ohio s in the central and southern ɔarts of the state. (Fig. 3.)

Fig. 2. Amber cane.

Non-saccharine sorghum embraces several divisions, the most common, and the only ones, representatives of which have been grown on the Station farm, are Kafir and Durra;[1] the former being characterized chiefly by erect, the latter by recurved heads.

Kafirs: In appearance the chief difference in the varieties of kafir is in color of seed and hull. At this Station only two varieties have been grown—Red and White—these having red and white seeds, respectively. While the Red grows taller (its height averaging 6 to 7 feet), and matures somewhat later than the White, it is more slender and at this Station has yielded a trifle less forage, though the difference is not significant. (Figs. 4 and 5.)

Durras: Of the durra group the variety of most importance which has been tested at this Station is Yellow milo or Milo.

[1]Among other renderings are such as dura, durrah, durrha, dourah and doura.

Compared with the kafirs it matures earlier and yields less forage but in the production of grain it is said to excel all the other sorghums. (Fig. 6.)

White durra, sometimes called "Jerusalem corn" is a durra of minor importance, which when grown on the Station farm several years ago, attained a height of 3 to 5 feet and yielded as an average of two years at the rate of 4.8 tons of green forage per acre.

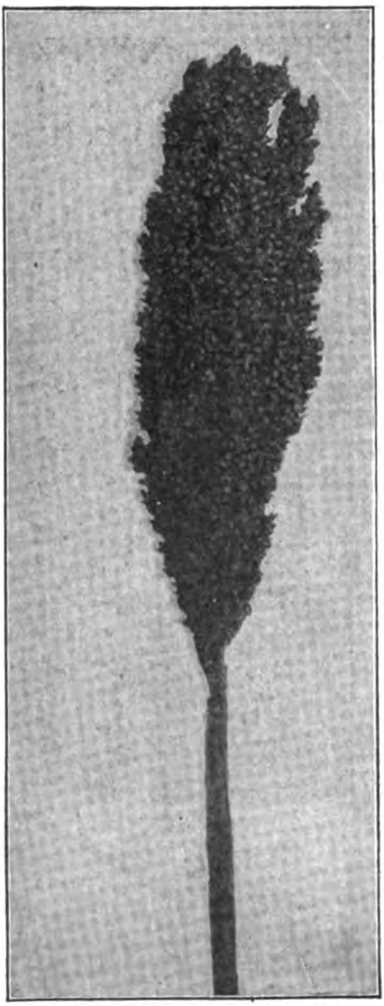

Fig. 3. Orange cane.

Feterita, another member of the durra group and a rather recent introduction from Egypt was grown on the Station farm one year, 1912, and of dry forage it yielded a trifle more than the German millet (one of the best) and considerably less than such sorghums as Amber and Orange cane.

Teosinte: Though belonging to a different species (Euchlaena mexicana), teosinte is so similar to sorghum in its cultural requirements that mention of it may be made here. It is a great stooler and in appearance resembles Indian corn.

In the South, on rich soil, where seasons are long and hot, and where there is an abundance of rainfall—conditions essential for its proper development—it is said to grow 10 to 12 feet high and to yield as high as 50 tons per acre of green forage which is highly prized both for soiling and for silage.

As a source of succulent feed in Ohio it is inferior to both corn and sorghum. On the Station farm it usually attains a height of about 5 feet.

CULTURE OF SORGHUM

Soil: The soil requirements for sorghum are much the same for corn. On rich land, or with the liberal use of fertilizers on or land, the yields are increased in the same proportion as are ose of corn.

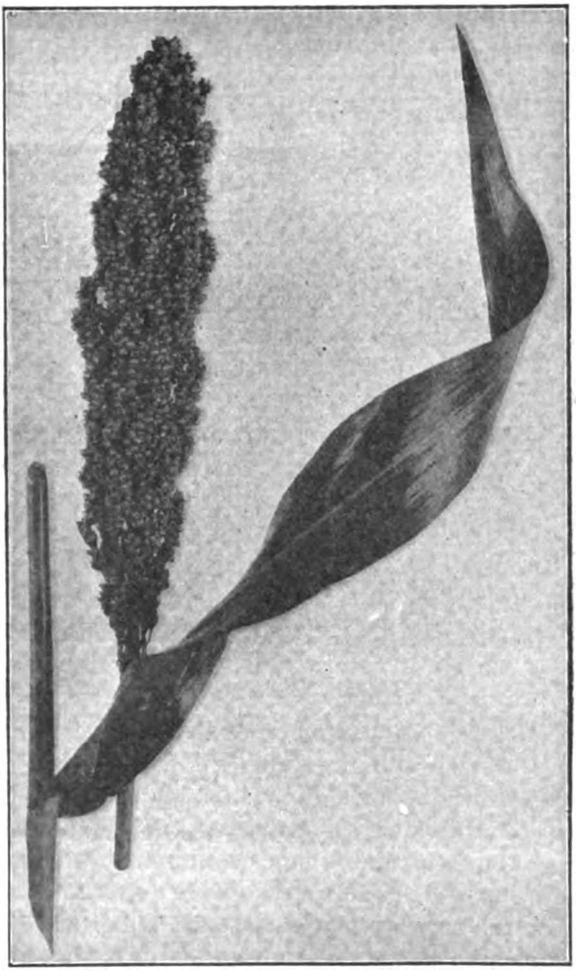

Fig. 4. Red kafir.

Since it is rather shallow rooted, and since it makes its growth in a comparatively short length of time it seems to exhaust, at least temporarily, the available plant food in the surface soil, hence its reputation of being "hard on the land."

Seed bed: The preparation of the seed bed is similar to that for corn. However, since the growth of the young plants, especially for the first few weeks, is very slow, a seed bed strictly clean, well packed and in good tilth, is desirable, else the young plants may be overwhelmed with weeds.

Seeding: In order to encourage a more rapid growth, seeding is best deferred until the ground is thoroughly warm, which, in the latitude of Wooster, is about June 1.

Fig. 5. White kafir.

Sorghum may be broadcasted or drilled solid, using about 1 bushel per acre, thus producing quite a fine quality of hay, or it may be drilled in rows, 36 to 42 inches apart, using 8 to 15 pounds of seed per acre and cultivating the same as corn. When wanted for soiling or silage the latter is the more common method.

The seeding may be done by the use of special plates in the corn planter, or the regular plates may be adapted, if necessary, by filling the holes with lead and subsequently boring new ones of the desired size. By stopping part of the hoes, a grain drill may be used.

Cultivation: During the period of its comparatively slow growth, especially if the sorghum is drilled solid, the use of a light harrow or weeder is important. It is advisable to drive parallel with, rather than across the rows. Later cultivation should be the same as for corn—frequent but shallow.

HARVESTING

Silage or fodder: For silage, sorghum is best harvested when seed is in the dough stage, using an ordinary corn binder. A re bitter silage results from earlier cutting and loss of nutrition n later cutting, as mature seed may pass through animals ligested. Its tendency to ferment renders it more difficult to p than corn, but when well served its feeding value is not :h inferior to that of corn.

If, instead of silage, it is zed as dry forage, the small dles may be set up and se-:ly tied in moderate sized :ks and fed from the field; or n it is dry—say 4 or 5 weeks r cutting—it may be hauled ie barn and stacked.

Having finer as well as more y and palatable stems, the forage is equal, if not superior orn.

Soiling: For soiling, sorg- may be cut at any time after s large enough to handle ly, though to best advantage the time it blooms until rds maturity. As a soiling , sorghum is consumed more :ly than corn and its resist- to drought makes it a valua- crop for the production of ulent feed during the hot, months of summer.

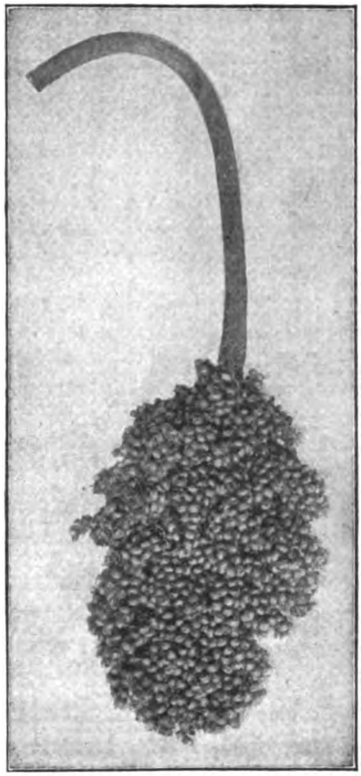

Fig. 6. Yellow milo. Three-eighths natural size

Hay: For hay, sorghum may it at any time after heading, gh for best quality it should be harvested shortly after bloom- A mowing machine may be used, setting it to cut as high as ible. On account of the succulence of the stems it should be ved to lie in the swath for several days before cocking and should ioroughly dry before stacking.

It may be expected to yield from 4 to 8 tons of dry forage icre.

Pasture: Some danger attends the pastúring of sorghum due to the development of hydrocyanic acid when the growth is checked as by drought or frost. After poisonous sorghum is cut and allowed to wilt, it is said to be fed with little or no danger. Bloat sometimes results from pasturing cattle or sheep on sorghum.

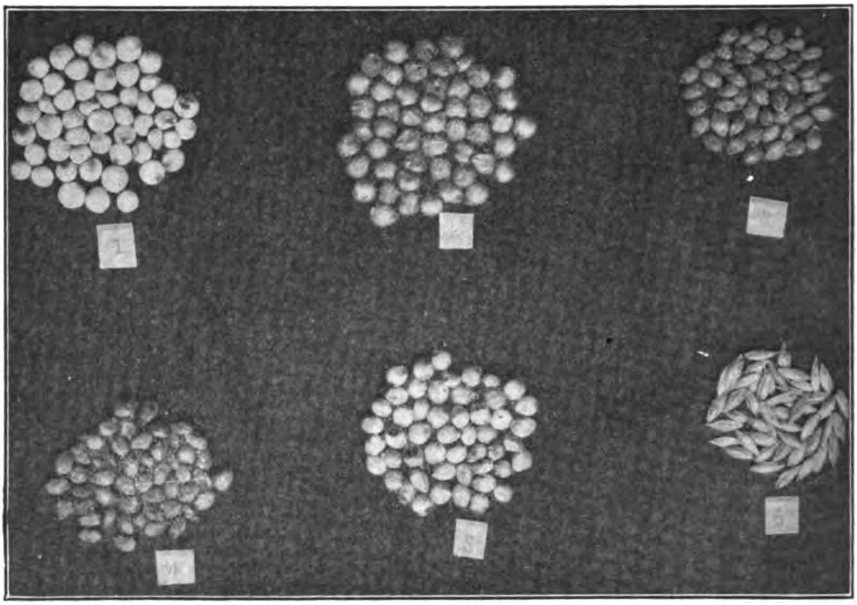

Fig.7. Sorghum seeds. (1) Feterita, (2) Milo, (3) Amber, (4) Orange, (5) White kafir, (6) Sudan grass (unhulled). Natural size.

SORGHUM AND COWPEAS

To get a better balanced feed, cowpeas are sometimes grown with sorghum, either seeding in rows and cultivating, using about 1 peck of each per acre, or seeding solid, using about 4 pecks of cowpeas and 3 pecks of sorghum per acre, After cutting, this mixture should lie in the swath a few days and then be put into cocks where it may remain for a considerable length of time.

At this Station, this combination has been tried several times, but always with unsatisfactory results. The sorghum, though fine, and attaining a height of 4 or 5 feet only, has usually choked out nearly all of the cowpeas, the few remaining being small and of little consequence. A mixture of Amber cane and New Era cowpeas yielded in 1911 and 1913, 6.8 and 14.8 tons respectively of green forage per acre.

MILLETS

The millets constitute another group of valuable forage crops. This is a general term applied to a great variety of cereal and forage grasses, differing widely botanically, but having this in common: All are rapid growing annuals, useful either as green or dry forage, and thriving best in midsummer.

USES

Millet is not usually looked upon as a regular staple crop, occupying a definite place in a fixed rotation, but rather as a substitute or emergency (catch) crop; one to be used in case of failure of clover or alfalfa or in case of the destruction by hail or otherwise of some crop like corn or potatoes.

Often, however, it is seeded not as the result of some seasonal catastrophe, but on account of its adaptation to some particular end. In the case of more intensive farming where two crops per year are desired, it is frequently seeded after the removal of a crop of rye or oats and pea hay. It enjoys quite a reputation as a weed eradicator and under favorable conditions as regards climate and soil, few weeds are able to cope successfully with a thrifty crop of millet. For this purpose it is second only to a summer fallow.

Under Ohio conditions millet is utilized almost exclusively as forage; largely as hay, but to a small extent also as a silage or soiling crop.

In some sections certain varieties are grown for the production of seed.

VARIETIES

A common grouping of the more familiar sorts is foxtail (Chaetochloa italica), broom corn (Panicum miliaceum) and barnyard (Panicum crus-galli).

Representative varieties of all these divisions have been grown by the Ohio Station in a small way, the results of which are reported in Table VI in terms of dry forage or hay.

TABLE VI. Millet: Tons of dry forage per acre.

Group	Variety	Year							
		1904	1905	1908	1909	1911	1912	1913	Av.
Foxtail	Hungarian	3.9	3.4	2.6	2.8	...	2.2	1.9	2.8
	German	5.1	6 1	...	4.8	6 6	3.5	4 6	5.1
	Red Siberian	3.8	3.0	...	3.4	3.9	2.1	3.0	3.2
Broom corn	Broom corn	...	...	...	...	5.4	2.3	1 9	3.2
	White French	5.1	4.4	2.6	2.4	4.7	2.3	1.5	3.3
	Early Fortune	...	...	...	...	0.6	2.0	1.5	1.4
	Black Voronezh	...	...	...	...	0.9	2.2	...	1.5
Barnyard	Japan	6.4	5.9	3 8	6.3	9.2	4.5	4.6	5.8
	Sudan Grass	...	...	...	...	...	3.9	4.3	4.1

Foxtail Millets: For Ohio conditions the most useful group of millets is the foxtail—characterized by an inflorescence or head of a single spike—and the varieties most highly prized are the Hungarian and German. For land in a poor state of fertility, or on richer land in the northern part of the state where the seasons are comparatively short, the Hungarian is preferable to the German, the latter being specially adapted to long seasons and to rich, river bottom land.

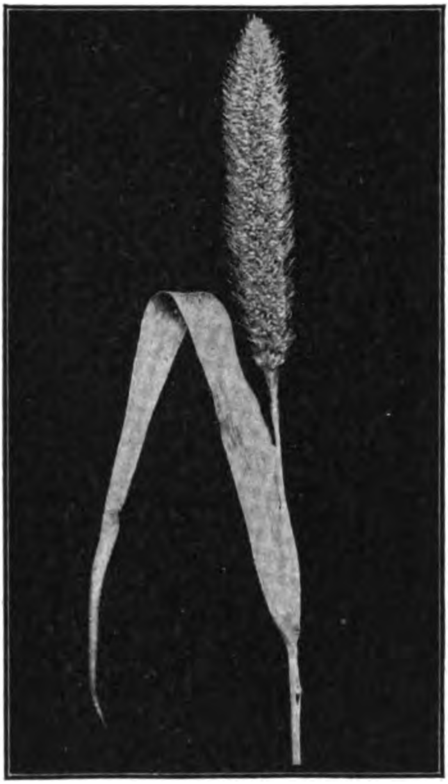

Fig. 8. Hungarian millet. Two-thirds natural size.

The Hungarian millet, or grass, as it is sometimes called, produces from each seed several slender and more or less branched stems upon which are borne rather narrow, dark green leaves and a short, nearly erect, bristly, compact and dark purple head. (Fig. 8.) The seeds are in part purple and in part yellow, the color of the latter possibly being due to immaturity.

The German is a rather coarse, vigorous growing variety, usually producing but one stem from each seed and that not branched. The leaves are somewhat short and broad and the nodding head consisting of clustered branches armed with purplish awns, may be an inch in diameter, 6 to 10 inches long, and bears small yellow seeds. (Fig. 9.)

The Red Siberian is somewhat earlier than the German. As it approaches maturity the heads take on a golden tinge. The color of seeds is a mixture of red and yellow, red predominating.

Broom corn millets: In this group of millets the head is a panicle like that of broom corn, hence the name. (Fig. 10.) They are grown for both seed and forage, chiefly seed, but in Ohio, and even in the United States, their culture is not general, it being restricted

gely to Europe. However, in
: northwest, in hot, dry seasons,
:se millets are frequently
·ded as a substitute for corn,
the feeding of hogs, hence
: common appelation of "hog
lets."

Compared with the foxtail
›up, the broom corn millets
usually shorter, coarser and
ds are larger and of more
ied color—white, yellow, red
ıearly black.

Of the varieties of this group
ted at this Station, the Broom
n and White French are the
ıt useful. In appearance and
it of growth these two varie-
are quite similar but in color
eeds they differ; the Broom
ı having yellow; the White
nch, white seeds.

The Early Fortune and Black
'onezh are smaller and earlier
ns and, in Ohio at least, are
e inferior to either the Broom
ı or White French. The
ly Fortune has purplish hulls
ı yellow seeds; the Black
cnezh white hulls and black-
seed.

Barnyard millet: This is
her name applied to the com-
barnyard grass—a plant of
: universal distribution and
.ried size, form and color in
rent sections of the country.
. 11.)

The most useful strain of
species—a variety often ad-
sed in seed catalogues as
ion Dollar Grass"—is one

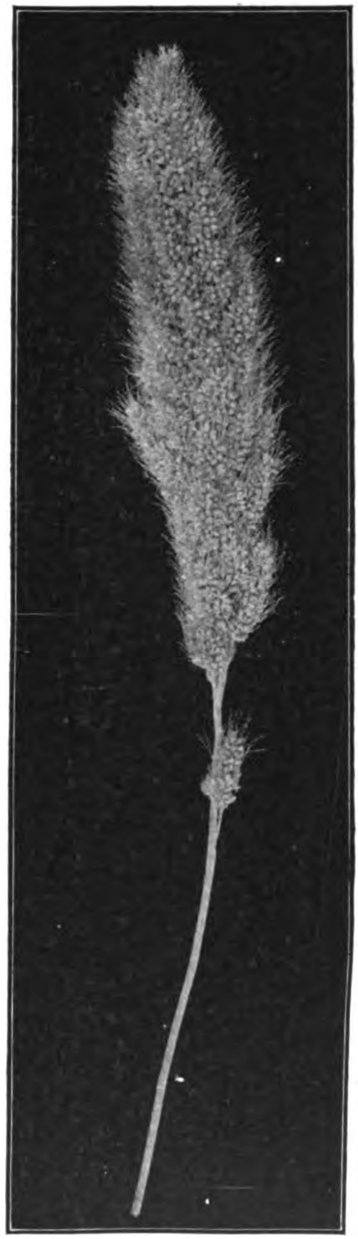

Fig. 9. German millet. Two-thirds natural size.

imported several years ago from Japan by the Massachusetts Experiment Station. According to the findings of that institution it may be regarded as useful for silage and soiling, but unsatisfactory for hay.

While this millet has surpassed in yield of dry forage all the other varieties tested at this Station, the quality of the hay is such, at least under Ohio conditions, that it cannot be recommended in preference to the members of the foxtail group.

Fig. 10. Broom corn millet. One-third natural size.

Pearl millet: Though technically not a millet, the coarse annual grass bearing cylindrical spikes, 6 to 12 inches long, resembling that of the cat-tail flag, is commonly spoken of as Pearl or Cat-tail millet, (*Pennisetum spicatum.*)

It suckers freely, and in the South, where length of season permits of two or more cuttings, it is highly prized as a soiling crop, yielding, it is said, as high as 40 tons of green or 16 tons of dry forage per acre. In Ohio the seasons are too short for its full development. On the Station farm it attains a height of 2 to 9 ft., but usually fails to come into full head.

Pencilaria, Horse millet and Mand's Wonder are a few of the many names under which it is frequently sold.

Sudan Grass: For the past two years, Sudan grass, a comparatively new introduction received from Prof. C. V. Piper, of the Bureau of Plant Industry, U. S. Department of Agriculture, has been included in the millet test of the Ohio Station, its cultural

requirements being similar to that of millet. Botanically, it is a close relative of sorghum, the original form of both being the well known, though sometimes troublesome, Johnson grass (sorghum halepense). Unlike the Johnson grass, however, it is strictly an annual, without rootstock, and has no weedy propensities. The inflorescence or head is a panicle like that of broom corn. The seeds are somewhat larger than are those of the broom corn millet and are reddish-brown in color. It is a vigorous growing plant having rather coarse forage (coarser than German millet) and at the Ohio Station attains a height of 3 to 5 feet. (Fig. 13.)

As may be noted from Table VI, in yield of air dry forage it compares very favorably with millet, it being surpassed in 1913 by the Barnyard and German and in 1912 by the Barnyard only. Little is known as yet regarding its feeding value, though Professor Piper reports that at Chillicothe, Texas, "horses ate it readily and perfectly clean."

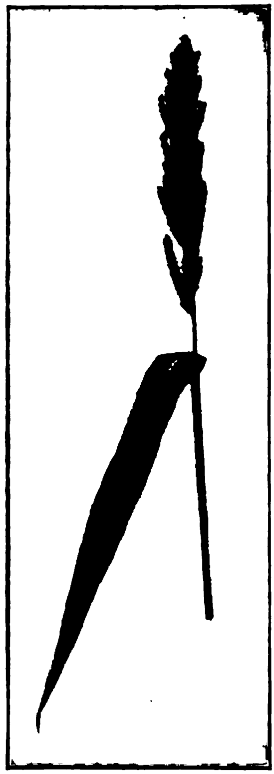
Fig. 11. Barnyard millet. One-fourth natural size.

CULTURE

Soil and fertilizers: Millet may be grown with varying degrees of success on most any kind of land; but on rich, mellow soils it does best.

Like sorghum, and for the same reason, millet bears the reputation of being "hard on the land." However, the exhausted effect usually passes away in a short time.

Well-rotted stable manure or readily soluble commercial fertilizers are best with which to enrich poor land for the growing of millet.

Seeding: In order to keep ahead of the weeds, millet should have all the advantages afforded by the preparation of an excellent seed bed—clean, firm, fine and moist.

Like sorghum, millet should not be seeded until all danger of frost is past and continued warm weather is assured. In favorable

seasons, seedings of the earlier varieties, such as the Hungarian, may be made, with chances of fair success, as late as the middle or latter part of July.

Millet may be broadcasted and harrowed in, or drilled with an ordinary grain drill, covering not to exceed 1 to 1½ inch deep.

When drilled solid as for hay, soiling or pasture, from 3 to 4 pecks per acre is none too much of the foxtail millets—the best for these purposes. If less than 3 pecks is sown the forage is apt to be coarse and unpalatable. If sown for either seed or silage, it is usually seeded in rows 24 to 30 inches apart—far enough to permit cultivation—using from 1½ to 2 pecks per acre—one-half that required for forage of fine quality.

When drilled solid, Barnyard millet is seeded a little lighter than the foxtail group, usually at the rate of about two pecks per acre.

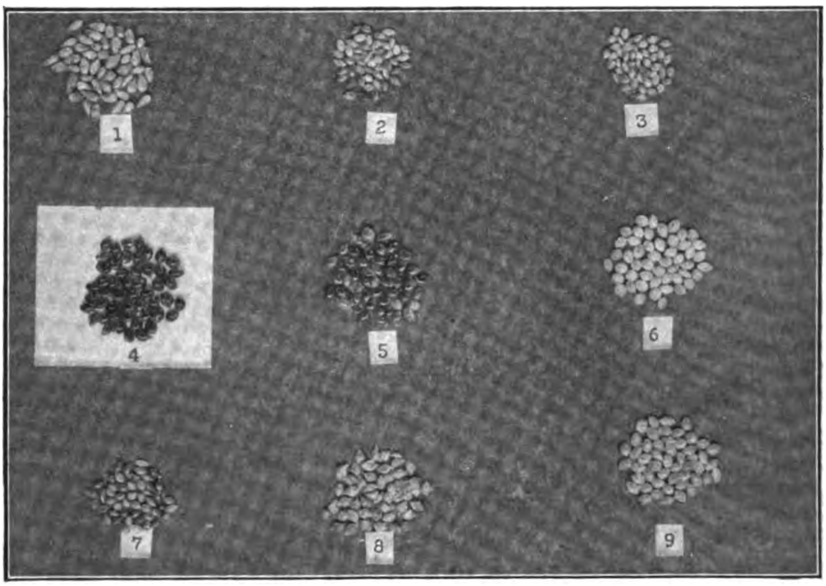

Fig. 12. Millet seeds. (1) Pearl, (2) Hungarian, (3) German, (4) Black Voronezh, (5) Early Fortune, (6) White French, (7) Red Siberian, (8) Barnyard, (9) Broom corn. Natural size.

HARVESTING

Hay: That some caution should be exercised in the feeding of millet hay has been shown by several experiment stations.[1] However, the danger is thought to be reduced to a minimum, if not quite eliminated, by cutting at what seems to be the most favorable time—when one-half or more of the plants are in head—and by feeding moderately and not too exclusively.

[1]N. D. Bul. No. 7. Mich. Bul. No. 117.

As millet approaches maturity it deteriorates as regards palata-ity and digestibility. Furthermore, the development of bristles ıy result in injury when fed to stock. It should never be allowed stand until the seeds e ripe.

The hay is cured ·actically the same as mothy. After lying for time in the swath it ıould be piled in cocks, ·here, on account of its oarseness, it will usually ıeed to remain a little onger than timothy.

When properly cut ınd cured, millet hay slightly exceeds timothy, both as regards composition and digestibility.

Soiling. For soiling, millet may be harvested any time after it is large enough to handle, usually 40 to 50 days after planting. For this purpose the foxtail millets are best, though some have obtained good results from the use of the Barnyard.

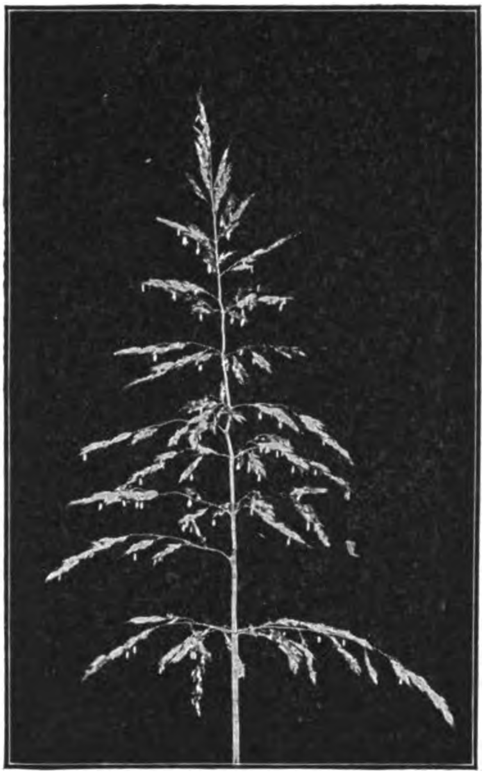

Fig. 13. Sudan grass.

Silage: Like corn, millet is most suitable for silage when the seed is in the dough stage.

Seed: When grown for seed, millet may be cut and threshed with the same implements that are usually employed in harvesting wheat and oats. The separator, however, should be so adjusted as to give lighter wind blast, and the use of finer riddles, preferably clover screens, is recommended.

So little seed is produced in Ohio that average yields, having significance, are hard to establish. In a favorable season a reasonable expectation is from 15 to 40 bushels per acre, depending upon the fertility of the soil.

The straw does not make very good forage. The hard, woody stems contain little nutrition and the beards are liable to collect in

the stomachs of animals. However, if well cared for and properly supplemented with grain, it can be made to answer for more valuable roughage.

Other cereal forage grasses of more or less merit in the production of forage are rye, wheat and oats.

RYE

Pasture: Not being a sod-forming plant, rye is not well adapted to pasturing, but in the absence of permanent pasture, or in order to avoid too early pasturing of blue grass, it is useful, as it will furnish green feed earlier than any other cereal or annual forage crop. Under favorable conditions it will be ready to pasture by the latter part of April. Unless intended for hogs it should not be allowed to come in head, as with age it loses its palatability. It is at its best when not over one foot in height.

Concerning rye, Prof. B. E. Carmichael, Chief in Animal Husbandry at this Station, writes:

"Rye has a high value for use as very early spring pasture, especially for sheep, which are not so likely to injure the soil and waste the green feed as are hogs. The latter may do considerable damage in early spring by trampling and by rooting. Rye may often be used to good advantage in late fall or during the winter, providing the condition of the soil does not prevent. It may be pastured in the spring by cattle with good results, but not so early as by sheep. The practice of hogging down mature rye has been highly regarded by some. Excepting in rare instances, this practice has but little to commend it, as the rye is worth no more per pound than corn, if quite as much, and, of course, yields far less.

"The growing of rye or rape, or both, in corn that is to be harvested by hogs, or on oats stubble, is in high favor with some on account of the considerable amount of valuable green feed that will be produced if the late summer season is favorable."

Silage: If occasion demands, rye may be put in the silo, though as compared with corn silage it is neither as palatable nor as nutritious. For this purpose it should be cut when heads are nicely out or not later than when in bloom, using an ordinary grain binder. On account of air in stems it should be packed thoroughly and this is greatly facilitated by setting the silage cutter to cut the stems short—about one-half inch.

Hay: Though not very palatable, chemically, rye hay compares favorably with that made from the leading perennial grasses. If cut when nicely in head, it makes fairly desirable hay and is eaten with moderate relish.

Under average conditions from 2 to 4 tons per acre of dry forage may be expected.

Cover crop: In the Ohio Station's work with cover crops, embracing 20 tests including 14 different plants and combinations thereof, thus far (4 years) rye has proved to be the most reliable. From the standpoint of fertility maintenance it is, of course, less desirable than legumes, but in the latitude of Wooster rye is more sure to go through the winter than any of the other crops tested. If possible to seed the latter part of July or the first of August, as in corn at time of last cultivation, rye and hairy vetch may be seeded together, using 4 or 5 pecks of the former and 20 to 30 pounds of the latter per acre.

WHEAT

While wheat is harvested almost exclusively as grain, yet, like rye, the green forage may be utilized as pasture, soiling, silage and hay.

Rank wheat, which is to be harvested for grain, may be pastured sparingly with hogs and sheep, providing the ground is not wet enough to poach, but such pasturing usually results in a slight reduction of yield, though in cases of excessive growth of straw it may result in a small increase of grain. Just when to pasture is difficult to determine as the after season has an important bearing upon the final outcome.

OATS

Pasture: Among the best spring crops for the production of early pasture are oats. As soon as they are 4 to 6 inches high—large enough to make a good mouthful—stock may be turned in. If desired, seed for permanent pasture may be sown with them and if pastured neither too heavily nor when the ground is too wet, little injury will result to the new seeding.

A slightly more desirable, and hence more satisfactory early spring pasture for cows and horses, is a mixture of oats, barley and rye—one bushel of oats and 3 pecks each of barley and rye per acre.

Though feasible, oats are in little demand for either soiling or silage purposes.

Hay: As a hay crop oats have several things to commend them. Pound for pound the hay is almost equal to clover and is superior to timothy. Clover is more likely to succeed when seeded in oats to be cut for hay rather than grain. Furthermore, it is an excellent crop with which to thicken a thin or old meadow. As soon as the weather will permit the oats may be disk-drilled in the thin clover

or timothy, using about 8 pecks per acre. Though oats and timothy do not mature together, yet, if cut at the proper time, the mixture makes hay of fair quality.

With reference to the best time to cut oats, there is considerable difference of opinion, but as the result of careful weighing and analyses of green oats cut at different stages of development, the South Carolina Station[1] concludes: "If a nitrogenous forage is desired, cut in the early milk stage when the whole plant is quite palatable; if a forage high in carbohydrates is desired, cut at the beginning of the dough stage; because, after this time, although there will be a continued increase in starch in the seed, the other parts are decreasing rapidly in feed value."

The value of oat hay depends somewhat upon the variety used, as among different varieties there is considerable variation both as regards quantity and quality of straw produced. In the five-year average of 36 varieties tested at the Ohio Station there was a difference in yield of straw per acre of 1,783 pounds.

Among the more leafy varieties having good quality of straw and, therefore, among the more acceptable for hay, are such as the Watson, Wideawake, Welcome and others.

Oats and field peas: Oats are frequently grown with field peas and the hay made from this mixture compares favorable with clover, not only in digestible nutrients but, also, when well cured, in palatability.

Adaptation: The culture of field peas is quite common throughout northern Ohio, but in the southern part of the state, where the temperature is somewhat higher, they are not at their best, though if seeded early, a fair crop may be expected.

Seeding: Both oats and field peas thrive best in cool weather and hence should be seeded as early in the spring as possible. The drill should be set—weighted if necessary—to put the peas in at least to a depth of 4 inches. If planted much shallower the peas are apt to dry up before maturity. The oats may be broadcasted or drilled at the same time (not the same operation) or, if the weather is favorable, a few days later, but before the peas begin to come up. If broadcasted, the oats should be harrowed in.

Three bushels per acre of this mixture is regarded as a good seeding, the proportion of each being varied to suit requirements. At the Ohio Station 3 combinations have been used, the results of which for 4 years are tabulated in Table VII.

[1]Bul. 163, p. 16.

TABLE VII. Oats and field peas. Pounds dry forage per acre.

Mixture of seed per acre	Year				4-year average	Protein	
	1909	1910	1911	1912		Percent	Lbs. per acre
2 bus. field peas—1 bu. oats...	4,200	6,650	4,900	9,960	6,427	10.1	649.1
1½ bu. field peas—1½ bu. oats	4,800	7,350	4,800	9,040	6,497	9.5	617.2
1 bu. field peas—2 bus. oats...	4,240	7,400	4,800	10,340	6,695	9.0	602.5

From this table it may be noted that the highest yield of total forage came from the heaviest seeding of oats and that the yield decreases as the proportion of oats decreases. As might be expected, in yield of protein per acre the reverse is true. However, the difference in quantity of protein is not great enough to leave much margin after allowing for the greater cost of seed incident to the use of the larger quantities of peas.

Therefore it would seem that when total tonnage is the chief object, oats should predominate, and when the chief object is feed of high quality the peas should be in excess.

A common proportion is 1½ bushel per acre of each, and in view of the greater possibility of lodging from the heavier seeding of peas, it may be regarded as one of the most satisfactory.

Varieties: Several varieties of field peas are offered on the market, such as the White Canada, Scotch Beauty, Black-eyed Marrowfat, but the one in most common use is the White Canada. This variety matures well with any of the midseason varieties of oats.

ROOT CROPS

Root crops is a rather indefinite term applied to a group of plants, chiefly biennials, having similar uses and adaptations and usually characterized by an enlargement of the primary root and stem.

Though they carry a small percentage of dry matter, they are an excellent source of succulent food possessing high dietetic value

So far as climatic conditions are concerned, root crops may be grown successfully throughout Ohio, but their culture is restricted by the rather limited conditions under which they can be utilized with profit, either as stock food or as a soil renovator.

As more and better succulent food can be produced cheaper with corn than with root crops, the growing of the latter for stock food is confined largely to the smaller farmers, the size of whose herds is such as not to warrant the erection of a silo.

Also, poultrymen, and dairy men who are feeding to make milk records, find it profitable to grow a few root crops.

As a soil renovator, root crops are of value in localities having heavy, clay soils as in many parts of northeastern Ohio. The ready access of air and water made possible by the decay of the roots of such crops has a beneficial effect upon tenacious soils.

Though the growing of root crops is not a prominent line of activity in Ohio agriculture, for the benefit of those who find them profitable, information regarding the culture of those most important in the state follows:

MANGELS

Soil and fertilization: A deep, rich, well drained loam is most desirable, though satisfactory crops may, with proper fertilization, be grown on the less productive clays and sands.

A calcareous, rather than an acid soil, is preferable.

They call for practically the same fertilization as corn. Like the latter they can make good use of phosphated manure—8 to 10 tons per acre being a good application. One hundred pounds of muriate of potash can likely be used with profit on most Ohio soils, as the crop is a heavy consumer of potassium. On land deficient in nitrogen—a condition indicated by lack of dark green color in leaves —80 to 100 pounds per acre of nitrate of soda will likely pay well.

Seed bed: Since the germination of the seed and the early growth of the plants are very slow, a seed bed of good tilth and free from weeds is important else the young plants may be overwhelmed by the latter. The nature of the roots calls for rather deep plowing and, where the topography and texture of the soil permits, this work may well be done in the fall, the manure, if any, being plowed under.

Seeding: Mangels are usually seeded from May 1 to 20, in rows 28 to 36 inches apart, using 5 to 10 pounds of seed per acre. They should be covered not to exceed three-fourths inch deep.

They may be planted with a hand drill or, by closing a part of the hoes, a grain drill can be adapted to this work.

Cultivation: Before the rows become visible, cultivation should begin, using such implements as a light harrow or weeder. After the plants are large enough so that the rows may be followed easily, cultivation with the ordinary sorts of implements should be frequent and should continue for 6 to 10 weeks, or until the tops cover the ground.

At the time the plants have about four leaves the process of blocking and thinning begins. Blocking consists in removing with a hoe all the plants in the row except little bunches 6 to 10 inches apart, the distance depending upon the variety. Immediately

thereafter the bunches should be thinned by hand to one plant. The hand thinning is very important and at the same time it is the most expensive and most laborious work connected with the culture of mangels.

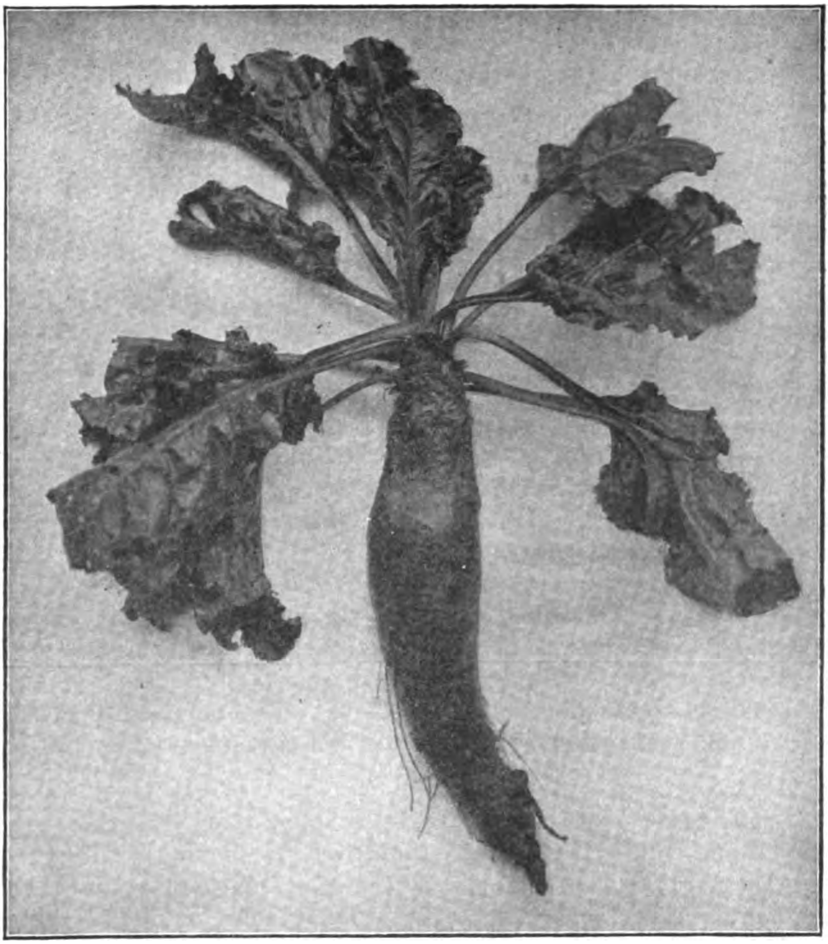

Fig. 14. Mangel (Long-red.) About one-sixth natural size.

Harvesting: Harvesting embraces three distinct operations—lifting, pulling and topping. Lifting consists simply in loosening the mangels—an act accomplished either by cutting a single furrow with a small plow on one side of the row or by the use of a double-pointed plow so constructed that a point passes on either side of the row.

The pulling and topping are usually done by hand, after which the mangels are thrown into piles.

Storing: In the absence of a root cellar, mangels may be "pitted" by throwing into ricks and covering with alternate layers of straw and earth, adding a layer of earth as the severity of the weather increases. In locating the pit an elevated site should be selected in order to provide good drainage.

Yield: The range in yield of mangels is large, varying from 15 to 40 tons. On the Station farm in 1911 they yielded at the rate of 21½ tons per acre.

Feeding: For most livestock mangels are cut into small pieces or sliced, though for poultry this is unnecessary. For a thousand-pound animal 25 to 50 pounds per day is regarded as a good feed; the amount depending upon the quantity of other feeds used.

Varieties: Mangels are usually classified with respect to shape, the chief forms being long, intermediate, tankard and globe. In color of flesh they may be white, pink, red, yellow, golden and purple or black. Varieties are often designated by coupling the names used to describe the mangels with respect to form and color, as Long Red, Golden Tankard, Yellow Globe, etc. (Fig. 14.)

In the long form the length of root (sometimes 20 or more inches) exceeds that of the breadth 3 to 4 times and one-half or more of the root may be below the surface of the ground, thus the successful culture of this type is restricted to deep soils. As may be inferred from the names, all the other forms of mangels have shorter roots and consequently are adapted to shallower soils, the globe type being especially suited to the lighter types of land.

The half-sugar mangel, said to be a cross between the sugar beet and mangel, is regarded as one of the best for stock food.

SUGAR BEETS

Sugar beets are mangels highly developed along the line of sugar production. Aside from composition they have come to differ from mangels with respect to size, shape, color, depth of growth and in keeping qualities. Sugar beets are smaller than mangels (fig. 15), usually conical (Vilmorin's Improved) or pear shaped (Klein Wanzlebener); rarely other than white in color; they grow entirely beneath the surface of the ground, consequently are difficult to harvest, and are less adapted than mangels for late storage in spring.

As the yield per acre is less and the cost of harvesting is greater than that of mangels, the latter are more satisfactory as a source of succulent feed.

On the Station farm in 1911 they yielded at the rate of 12½ tons per acre.

The culture of sugar beets is essentially the same as that of mangels. The former, however, are usually seeded thicker than the latter; the usual rate per acre for sugar beets being 15 to 20 pounds, and in rows 18 to 24 inches apart.

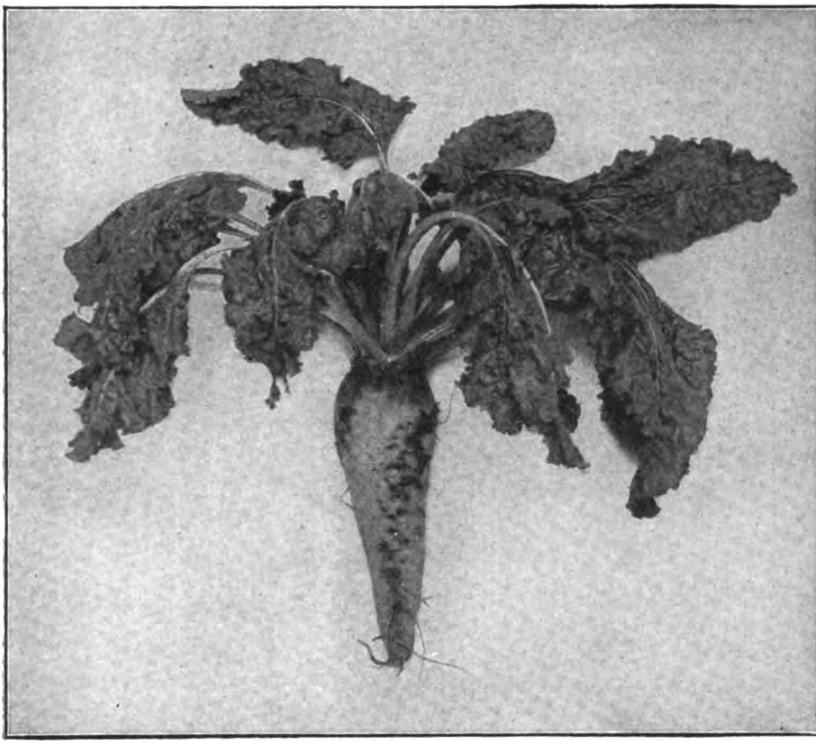

Fig. 15. Sugar beet.

For the production of sugar, the culture of beets is restricted to a comparatively cool climate; such as that which predominates throughout the region of the northern limit of the corn belt. In warmer climates they are not only more subject to disease but often the content of sugar is too low for profitable production.

TURNIPS

Adaptation: With respect to soil, turnips thrive best on silt loams; stiff clay and sandy soils not being well suited, the former on account of the difficulty with which a finely pulverized seed bed is prepared, the latter on account of incapacity to hold moisture. Like mangels, turnips thrive best on a calcareous soil. Not a great amount of sunshine is required, a cool, damp climate being favorable.

As compared with the white-fleshed varieties, the yellow-fleshed grow less rapidly, are firmer, have higher feeding value, are more resistant to frost and may be kept sound for a much longer period of time.

RAPE

Classification and adaptation: Though not looked upon as a root crop, botanically rape is a close relative of mangels and turnips, all being members of a well known and populous group—the mustard family.

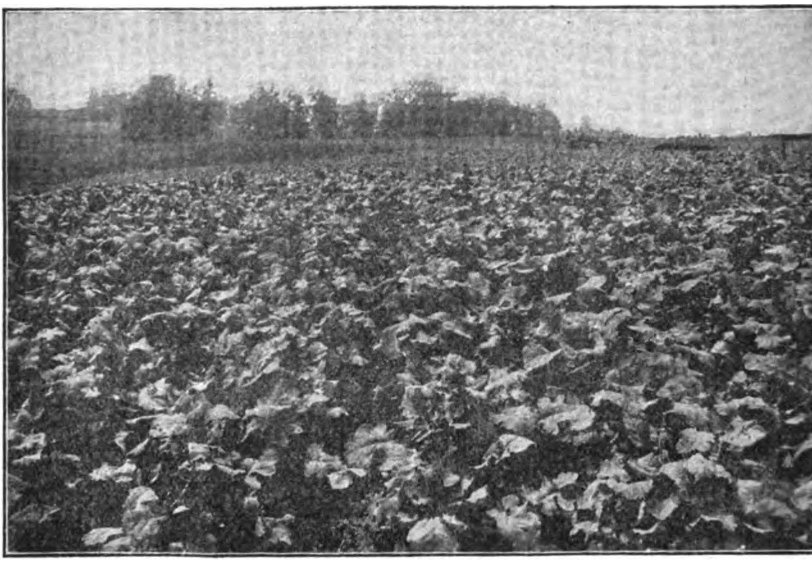

Fig. 18. Rape, drilled in rows; 59 days after seeding.

The soil and climatic adaptation of rape is similar to that of turnips. It is partial to rich loams and, like corn, it responds readily to liberal applications of stable manure and fertilizers.

It calls for the preparation of an excellent seed bed; one which is firm, fine and moist.

Seeding: The usual time of seeding is from April to July 15, though in some years the weather permits of successful seeding as early as the latter part of March. As a catch crop it may be seeded in corn at the time of last cultivation and in the same manner as turnips.

It may be sown solid (broadcasted or drilled) or in rows 24 to 28 inches apart. For seeding in rows a hand drill may be adjusted or a grain drill may be adapted by closing a part of the hoes. The

seed is best distributed from the grass-seeding attachment of a drill, piping the seed through the hoes, setting the drill to cover it completely though not deep. If broadcasted, 5 to 8 pounds of seed per acre are required; if drilled in rows, 2 to 3 pounds are sufficient.

Cultivation: Seeding in rows permits of cultivation which results in a more rapid growth and, during the pasturing season, less is wasted by trampling. (Fig. 18.)

Unlike mangels, rape grows rapidly from the first, and if given about three cultivations at intervals of one week, it should be ready to pasture in 6 to 10 weeks.

Regarding the value of rape as a forage plant, Prof. B. E. Carmichael writes:

"Rape has proved a very valuable source of green feed for both sheep and swine at the Ohio Station. Sheep and lambs will do well on rape with no grain. Young hogs, or, indeed, hogs of any age that are expected to yield rapid gains, should be provided with a fairly liberal grain ration in connection with rape pasture. On account of the large proportion of crude protein in rape, there is much less need for nitrogenous supplements in connection with corn and rape than with corn in dry lot. Bulletin 242 gives the results of a number of experiments in which use was made of rape for swine."

If not pastured too closely, rape will continue to furnish green forage throughout the season, the amount varying with the fertility of the soil.

Varieties: While there are numerous types of rape, including many hybrids and crosses, yet all may be grouped in two classes: annual or summer, and biennial or winter rape.

From the seed, an oil is extracted which is used for lubricating and lighting and the refuse or "rape cake" is highly prized as stock food and fertilizer.

The biennial or winter rape, of which the Dwarf Essex is a leading variety, is the kind commonly grown in this country for forage. This type produces seed only in localities where it can withstand the winter. Most of the seed used in this country is imported from Europe.

EXPERIMENTS IN WINTER LAMB PRODUCTION

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., FEBRUARY, 1914

BULLETIN 270

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

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BULLETIN

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Ohio Agricultural Experiment Station

NUMBER 271 FEBRUARY, 1914

A CHEMICAL STUDY OF THE NUTRITION OF SWINE

By E. B. FORBES, F. M. BEEGLE, C. M. FRITZ AND J. E. MENSCHING

One of the important problems of the Corn Belt is the economical use of corn. The feeding of corn *is* a problem because there are some purposes which it serves exceedingly well, and others which it serves very poorly. Swine are fed more largely on corn than on any other food, and a large percentage of the American corn crop is fed to swine. It is important, therefore, that we understand the specific effects of corn when fed to animals, especially to swine, and also the effects of those supplementary foods which are fed with corn. The object of this investigation was to furnish such evidence on this subject as could be obtained by balance experiments, in which by the chemical analysis of food and excreta, it is possible to determine the nutritive status of the animal with reference to each one of the food constituents. Thus, with reference to calcium: while fed on corn alone the growing pig receives in the food a certain amount of this element. In the urine and feces we find more calcium than was present in the food; that is, on corn alone the pig loses calcium; the calcium balance is negative. Such is the evidence.

Especial attention is given in this study to the mineral nutrients, because corn is deficient in some of these, and also to those supplementary foods which are used with corn, since they differ much in their ability to make good these mineral deficiencies.

This investigation as a whole was intended as a preliminary to a further and more extensive study of this problem, especially by feeding and carcass-analysis experiments. The observations cover the following points:

1. Digestion of foods.
2. The balance of mineral acids to bases.
3. Effects of magnesium on calcium metabolism.
4. The significance of creatinin excretion.
5. Mineral requirements and paths of elimination.

PLAN OF EXPERIMENT

Five cross-bred Yorkshire-Chester White barrows, 6 months old and all from the same litter, were the subjects of this experiment. Confined in metabolism crates they were taken through eight 10-day collection periods, separated by 7-day intervals on the next ration to follow, the change of food being made abruptly at the end of each collection period. The five animals were given the same food, our results, therefore, being based on five repeats.

The foods used in the several periods were as follows:

1. Corn.
2. Corn; soybeans.
3. Corn; linseed oil meal.
4. Corn; wheat middlings.
5. Corn; meat meal (digester tankage).
6. Corn; skim milk.
7. Corn.
8. Rice polish; wheat bran.

They were, therefore, the common practical foods for swine in this country, except ration No. 8, composed of rice polish and wheat bran, these feeds being selected on account of their very high content of magnesium in proportion to calcium. Corn was fed alone in the first and seventh periods to show any such changes as might be due to the long continued routine or to increasing age.

The observations covered the usual proximate analysis of foodstuffs and feces, daily nitrogen, creatinin and ammonia estimations on the urine, also determinations of the sodium, potassium, calcium, magnesium, sulphur, phosphorus and chlorine on foods, urines and feces, and further, a slaughter test on the five animals after the termination of the experiment.

METHODS OF EXPERIMENTATION

The metabolism crate used combines features from Gies's dog crate, Grindley's sheep crate, and McCollum's pig crate with ideas of our own, and was found to be entirely satisfactory for the purpose. Four of the crates are shown in Plate I, p. 227. The objects which we sought to attain in designing this crate were freedom of movement of the animal, free circulation of air, and the accurate collection, without admixture or contamination, of the excreta.

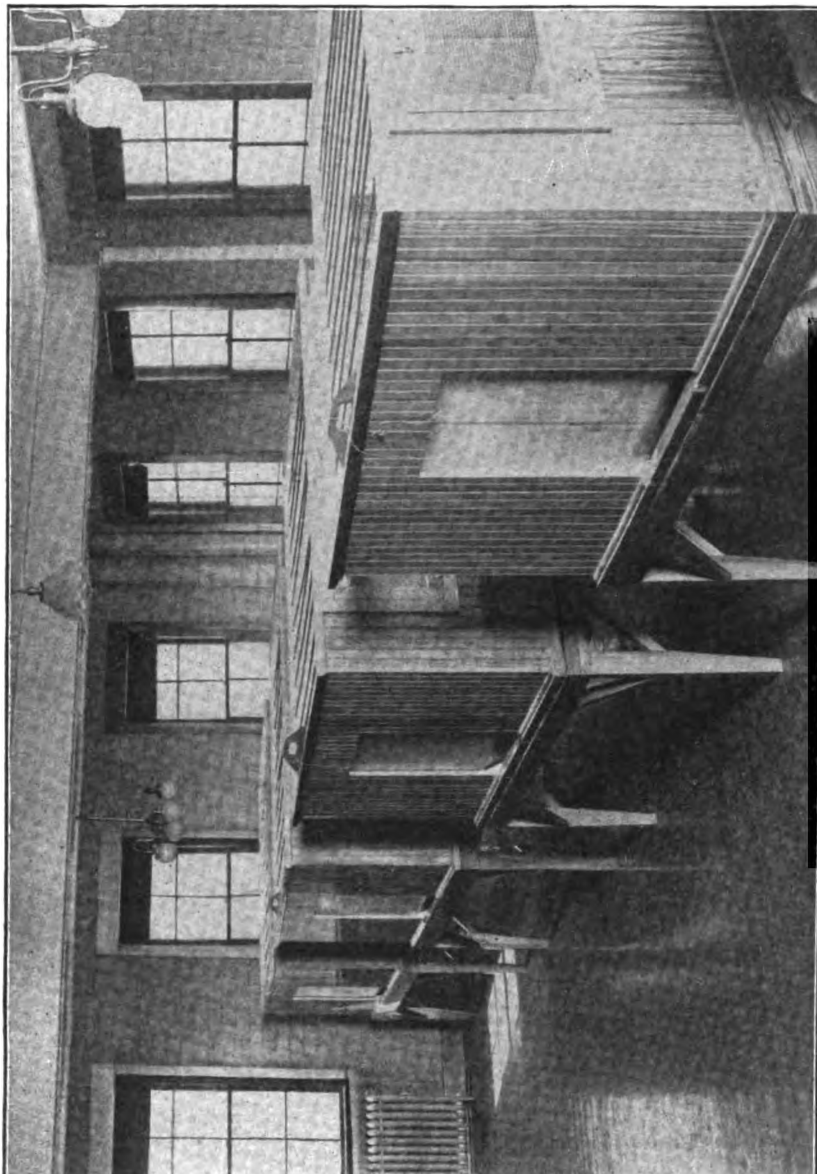

PLATE I Metabolism crates—Five such were used.

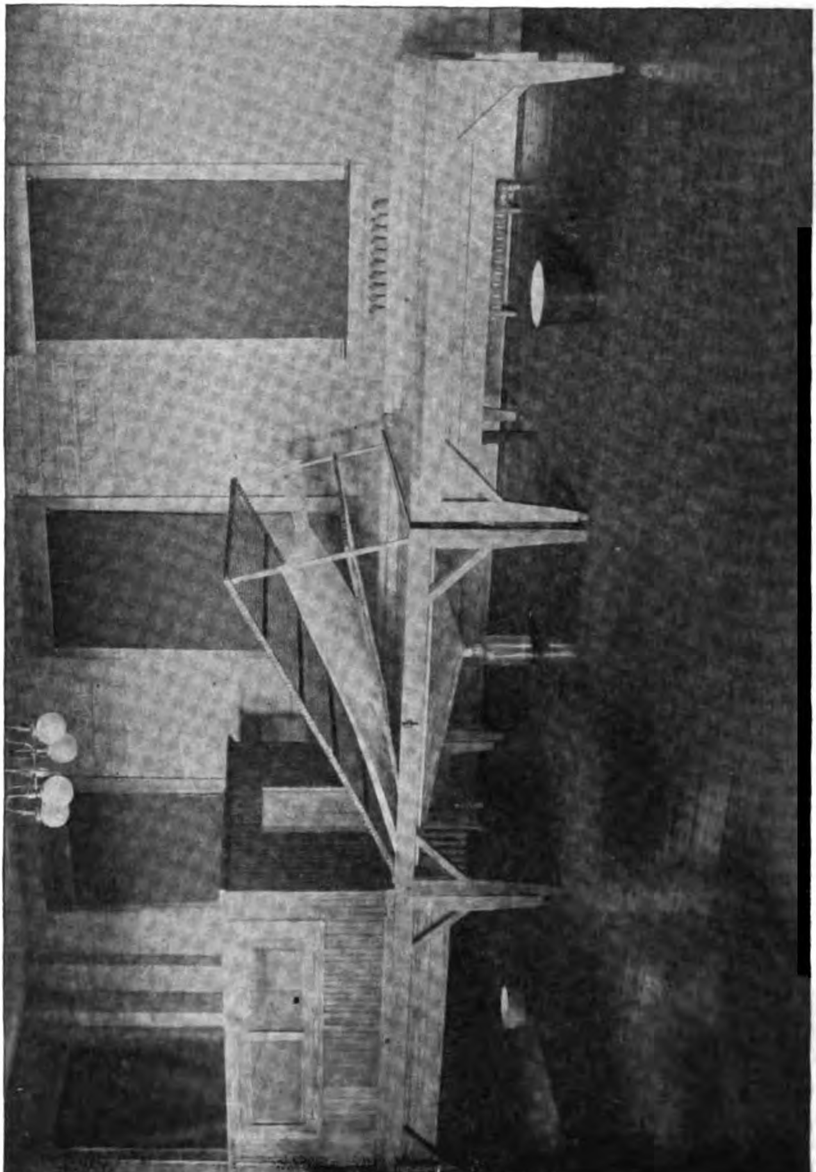

PLATE II Metabolism crate—Top removed, screens and cloth elevated.

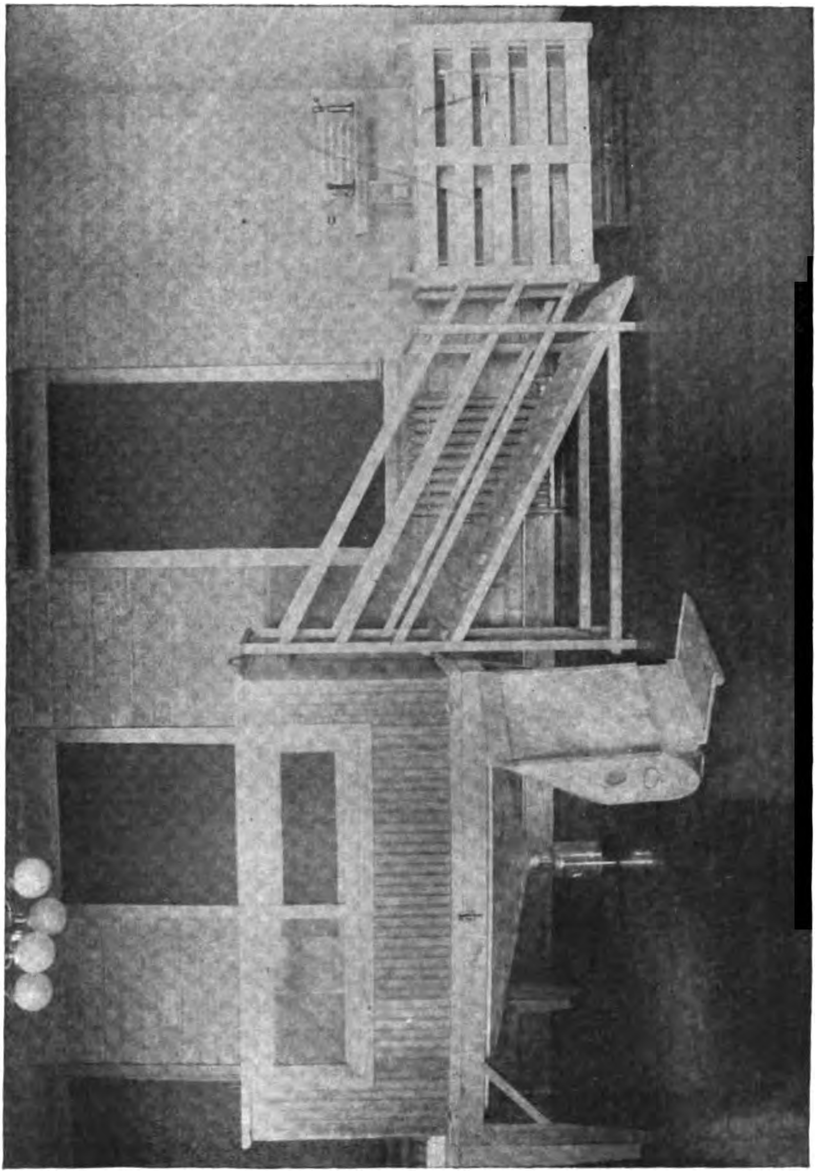

PLATE III Metabolism crate, feed box, equipment for weighing.

In Plate II, p. 228, the removable crate, which runs on rollers, has been shoved over onto the cleaning table, the pig walking along with the crate, and the screens have been elevated to show their relation to one another. When in place, the light screen below rests four inches beneath the heavy upper one on which the pig stands. It is used simply to support a fine cloth which retains the feces but allows the urine to pass through into the hopper, and then through a plug of cotton into a bottle under the crate. The cotton and bottle are both treated with thymol. The drain table at the right is used in scrubbing the heavy screen. The two cleaning tables mentioned are covered with galvanized iron, and are built to drain to an outlet. They are on casters and are pushed from crate to crate for the daily cleaning and collection program.

Plate III, p. 229, shows the chute, weighing crate and scales used in weighing the pigs, and also a feed box. The food was placed in the boxes in another room, and the boxes were then attached to the crates with a single hook, each, after raising the sliding doors shown in Plate I. After the food was comsumed water was given in the same trough by pouring it in through the hole shown in the end of the feed box. This hole is closed with a slide door. Small amounts of food sometimes falling upon the little platform attached to the feed box were returned to the trough, and were consumed with the next feed.

The pigs were fed twice daily. The foods given during each period were all weighed at the beginning of the period, and samples for moisture and fat determination were taken at this time, complete analyses having been made before the beginning of the experiment.

Repeated attempts were made to apportion the food in accord with the creatinin elimination, and the water in accord with the amount of food, but we found it impracticable to adhere in all periods to the first principle, and the second was abandoned entirely, the desire of the animal for water standing in no definite relation to the food consumed. Water, therefore, was generally given *ad libitum*, but measured.

The pigs were scrubbed daily with distilled water to which was added a little phenol, but no account was taken of cutaneous elimination in the experimental work. During intermediate periods the pigs were scrubbed with soap.

Unless the pigs were washed frequently they became sticky and uncomfortable. Then they rubbed off hair which fell into the feces, and had to be picked out in the preparation of the samples for analysis.

One would naturally suppose that the comfort of so dirty an animal as a hog would require no washing, but as a matter of fact a

pig does not prefer to be dirty. Because of his heavy overcoat of fat he wants first to be cool. To be cool, he must be wet. His only way to get wet, ordinarily, is to wallow in mudholes. Incidentally, he also frees his skin from its secretions, and thus completes his comfort.

By the use of wire brushes the feces were removed daily from the upper screen and from the cloth, and were placed in friction-top cans in a cooling room at about 0° F. The urine cloth was washed daily in boiling distilled water, as also were the lower screen and urine hopper. These washings were added to the urine sample. The heavy screen was scrubbed at the end of each 10-day period, and this wash water was also added to the urine sample.

The urine was collected morning and evening, and kept in a cooling-room at 32° F. Each morning the urines from the day before were measured, and aliquots taken out for preservation and for the daily determinations. The determination of the inorganic elements in the urines of the first period was omitted because of errors due to the precipitation of phosphates in the urine bottles. This difficulty was obviated in subsequent periods by the use of 10 c. c. of acetic acid in the day's urine on placing it in the cooler. The feces were marked by the feeding of carmine, and were sampled at the end of the period by grinding in a frozen condition, in a power sausage mill.

Chemical analyses were made in triplicate by methods as follows:

Moisture: Vacuum method, over sulphuric acid.

Nitrogen: Kjeldahl method; on foods and feces by the Gunning-Arnold-Dyer modification; on urine, according to Hawk.

Fat: Ether extract.

Ash: On foods by the hydrochloric acid leaching method; on feces by the water leaching method.

Crude fiber: Original; see Ohio Bul. 255.

Carbohydrates: By difference.

Metabolic nitrogen: Pepsin digestion method.

Urinary ammonia: Folin method, as modified by Steel.

Creatinin: Folin method.

Sodium: Original; see Ohio Bul. 255.

Potassium: Lindo-Gladding method.

Calcium: McCrudden's method.

Magnesium: McCrudden's method.

Sulphur: Peroxide and carbonate methods.

Chlorine: Provisional method of the A. O. A. C.

Phosphorus: Official gravimetric method after nitric-sulphuric acid digestion.

NOTES ON METABOLIC NITROGEN DETERMINATION

The nitrogen of the feces is found in (1) food residues, (2) bacteria, and products of their metabolism, (3) epithelium from the digestive tract and (4) residues from bile and digestive juices.

From this heterogeneous group of substances we desire to separate those portions which represent digestible food constituents. This fraction is of interest especially as giving us a basis for the determination of the amount of nitrogen in the feces which represents *indigestible* food constituents. The digestibility of the food nitrogen is determined by dividing its amount into the same, *minus* that of the indigestible feces nitrogen.

At best, from the nature of the case, this estimation embraces a considerable element of conventionality. Certainly no known method gives a scientifically accurate result; still there is considered to be ample warrant for the determination, in its practical usefulness.

The largest sources of error in the determination of metabolic nitrogen by the usual pepsin-hydrochloric acid method are as follows: (1) The indigestible food nitrogen may have become partially soluble in pepsin-hydrochloric acid during its passage through the alimentary tract. This factor would tend to exaggerate the metabolic nitrogen and thus to lead to overstatement of the digestibility of the food nitrogen. (2) The digestibility of bacteria and their metabolic products contributes to the determination an element of error the nature and degree of which have not been determined.

As to the practical accuracy of the method, we find one bit of evidence in our results. The nitrogen of skim milk, which presumably is practically all digestible, appears, from our results with the pepsin-hydrochloric acid method, to be digestible to the extent of 99.12 percent. The net error of the method, therefore, would seem not to be large.

BEHAVIOR OF THE ANIMALS

The progress of the experiment was marked by no unfavorable incidents of moment. The pigs remained in good health, and did not appear to suffer from the confinement. In hot weather they were kept comfortable with electric fans. The gain in weight was very satisfactory for pigs so fed, and it seems to us unlikely that such an investigation could well be carried out under more favorable circumstances than attended this series of experiments.

DIGESTION OF FOODS

The literature of animal husbandry is strikingly poor in data on the digestibility of foodstuffs by swine, and the experimental work upon which rest the very few figures available is exceedingly scanty.

The digestion coefficients which we are reporting (Table IX, p. 248) are based on five repeats, the detailed data being given in previous tables.

The digestibility of corn in the first and seventh periods is very nearly the same, the only notable difference being that the crude fiber of the corn in the seventh period seemed to be less digestible than in the first. In consideration of the small amount of crude fiber in corn this difference in digestibility in the two periods is of no importance.

The digestibility of the protein of the cereal and leguminous seed products is remarkably constant, the averages of results from the five individuals varying but two percent. The protein of meat meal, however, is several percent less digestible, and the protein of milk is several percent more digestible than the protein of the foods of vegetable origin. The low digestibility of the protein of the meat meal is perhaps due to the presence of hair and other refractory nitrogenous substances, or to the high degree of heat to which it is subjected.

The admixture of soybeans, meat meal or skim milk with corn so increases the digestibility of the starch of the corn that the apparent digestibility of the carbohydrates of the supplementary foods becomes over 100 percent.

In the same way meat meal and skim milk, when fed with corn cause such a decrease in feces ether extract as to make the digestibility of the fat of these foods apparently much more than perfect, the percentage of digestibility of the fat of skim milk seeming to be about 162 percent, and of the meat meal 139 percent, which facts suggest the prominence of bile residues in feces ether extract, and also the fact that the determination of digestibility of ether extract is, to borrow an expression from Thudichum, "a ceremonious delusion."

A still more anomalous condition exists with reference to the effect of meat meal and skim milk on the digestibility of the crude fiber of corn. These supplements so decrease the digestibility of the crude fiber of the corn with which they are fed that the crude fiber of meat meal which is present to the extent of 4 or 5 percent, because of the inclusion of a certain amount of paunch contents, seems to be digestible to the extent of 101 percent less than nothing, while the skim milk when fed with corn becomes chargeable with an extensive minus digestibility of crude fiber, of which, of course, it contains none at all. These effects of the supplementary feeds on the digestibility of the crude fiber of corn may be considered as an expression of their influence on the bacterial flora of the alimentary tract.

Digestion coefficients of less than nothing, and of more than 100 percent, show that the determination of digestibility of supplementary foods by difference, in the usual way, is not free from objection, since the supplement affects the digestibility of the basal ration, which the method assumes to be constant. It seems to us more nearly correct, however, to use the figures obtained than to call all minus coefficients zero, and to give a value of 100 percent to all those which seem to be above that figure.

In general our digestion coefficients are decidedly higher than the collected figures for some of the same foods as quoted by Henry in his "Feeds and Feeding."

Consideration of the magnitude of possible analytical errors and their bearing on the above results leads us to the conclusion that the anomalous character of the digestion coefficient for the nitrogen-free extract of soybeans is possibly, though not probably, due to experimental error. We are not able to account for any of the other coefficients of more than 100 or less than zero in this way. They apply, however, to constituents which are present in small amounts, and hence are not of great practical significance.

THE BALANCE OF MINERAL ACIDS TO BASES

Each of the rations contained an excess of acid to basic mineral elements. (See Table X, p. 249.) The magnitude of this acid-excess proves the pig to possess an extensive acid-neutralizing capacity.

The urinary ammonia excretion was found to vary directly with the excess acid of the ration (See Table X) provided that the protein of the ration remained about the same in amount, but any considerable increase in the latter also increased the urinary ammonia.

From the figures in Tables X, XI and XXI we do not see evidence of a close relation between calcium retention and either the excess of acid over basic mineral elements in the ration, or the urinary ammonia. This factor, therefore, seems not to be important in this connection in practical rations for swine, though of this fact we can not be certain, since we are unable to differentiate between the effects of calcium deficiency and acid excess.

With a constant calcium content such variations in mineral acidity as were present in these rations would doubtless affect calcium retention, but the variations in calcium intake in these cases were of so much greater magnitude than the variations in mineral acidity that the effects of the latter on calcium retention were not discernible.

The retention of calcium, however, (Table XII, p. 251) appears to be closely related both to the intake of calcium and to the ratio of calcium to magnesium in the food, stated in chemically equivalent

units; but our evidence does not make it possible to judge with certainty of the relative influence of these two factors. The greater loss of calcium in Period VIII than in Periods II and VII, however, in spite of greater intake, is probably due to the much greater proportion of magnesium to calcium in the food. The excess of magnesium to calcium in Indian corn is probably not an important factor, since neither one was present in sufficient amount to maintain equilibrium in these growing pigs.

CREATININ EXCRETION IN SWINE

Creatinin excretion (See Tables X and XIII, pp. 249 and 251) was shown to be a definite function of the individual animal, to increase with the growth of the animal, and to be entirely independent of the amount or kind of food.

A slaughter test at the end of the experiment (See Table XIII) showed that the five individuals compared with one another as to creatinin excretion in exactly the same order as with regard to the weight of each of the following: the live animal, the dressed carcass, the total flesh, the blood, and the bones. In regard to the internal organs, brain, lungs, liver, kidneys, and spleen, we failed to note such a regular correspondence with creatinin excretion.

During the first and seventh periods the pigs were fed on corn alone, the amount fed in the seventh period being slightly less than the amount fed in the first. In the seventh period, however, the pigs weighed 2½ times as much as in the first, and they excreted 2½ times as much creatinin. The relative creatinin excretion of the five pigs remained practically the same during five months.

These observations are in harmony with the conclusion of Folin that the creatinin of the urine is a product of endogenous nitrogen metabolism.

MINERAL REQUIREMENTS AND PATHS OF ELIMINATION

The extensive series of mineral balances in Tables XIV-XX show that in such a variety of practical rations it is impossible to reckon mineral requirements in a definite way, the reason being that the amount of a given mineral element necessary to maintain equilibrium is much affected by the other constituents of the ration. An amount which is quite sufficient for maintenance, or which even provides for marked retention, may be quite insufficient for maintenance under other dietary conditions. We shall, then, place emphasis more especially on the foodstuffs, as such, in relation to mineral balances, than upon the amount of their mineral constituents.

compounds; but soy beans are not rich in calcium; at best they could not possibly sustain liberal calcium retention. The high calcium content of leguminous plants as a whole is much more characteristic of their leaves and stems than of their seeds.

It is not apparent that in any case an abundance of feces phosphorus is responsible for negative calcium balances.

The magnesium balance was not at all closely in accord with the intake. On about 2.25 gm. intake with soy beans there was retention; with about 9.25 gm. intake on wheat bran and rice polish there was loss. The magnesium loss was through the feces. This high fecal outgo of magnesium seems to have been due in part to the enormous phosphorus intake, but apparently not to this factor alone.

The magnesium of the food is shown to be a prominent factor in the partition of the phosphorus between urine and feces, an increased proportion of magnesium to phosphorus in the food increasing the proportion of feces phosphorus to urine phosphorus. There was no such prominent effect of magnesium to restrict phosphorus retention.

Magnesium balances were negative on the rations containing linseed oil meal, meat meal, rice polish and wheat bran, and also on the ration of corn alone. Magnesium was retained only from rations containing soy beans, wheat middlings and skim milk. That magnesium should be so commonly deficient in these practical rations is surprising.

The phosphorus balances in these experiments were all positive except for one individual on the ration of corn alone. In no case, however, was there any considerable retention of phosphorus on this ration. Except in one case the phosphorus retention in the several periods was in the same order as the intake. This exception was the ration containing wheat middlings. The peculiarity of the phosphorus of this ration was a large proportion of triticonucleic acid, and the phosphorus of this ration was much less efficiently retained than the phosphorus of the rations containing meat meal and milk. With a much smaller intake of phosphorus in meat meal and milk the retention was much greater. Two circumstances unfavorable to phosphorus retention in the wheat middlings ration were the presence of much less calcium and much more magnesium than in the meat meal and milk rations. The results were increase in both urine and feces phosphorus.

During the feeding of skim milk there were lower proportions of potassium, magnesium, sulphur, chlorine and phosphorus in the feces than during any other period; and this period was also characterized by the maximum percentage retention of the calcium, magnesium, sulphur and phosphorus intake.

Corn is shown to be more deficient in calcium than in any other nutrient; its magnesium content is also low, and its phosphorus content allows of but slight retention. At the same time the nitrogen retention is quite considerable. It is true that the pigs were not on what would ordinarily be considered as full feed, but we do not believe that this fact decreases the significance of our results, since the amount of corn consumed was sufficient to provide for considerable nitrogen storage. In spite of the slight retention of phosphorus we consider its amount insufficient, since we have here hardly more than the requirement for maintenance, at a time of life which would naturally be characterized by extensive storage of phosphorus.

The results, in general, show that the mineral requirements of swine are apt not to be satisfied during cereal feeding. A dry-lot fattening process probably involves, as a rule, considerable draft upon mineral stores previously accumulated during periods of access to green feeds.

Other ideas than those in this article, have been expressed, regarding the nutritive deficiencies of corn. Thus T. B. Osborne (Science, Jan. 31, 1913) writes:

"The results here presented leave no doubt that the deficiency observed in the practical feeding of corn meal is explained largely, if not wholly, by the unique chemical constitution of zein which forms such a large part of its proteins."

Our results show that, whatever the protein deficiencies of corn, its mineral deficiencies are more pronounced, since, in balance experiments, the deficiencies in calcium and other minerals are immediately made manifest by negative balances or deficient storage, while the protein deficiencies, whatever their nature, allow liberal nitrogen retention.

A considerable degree of independence exists between nitrogen and mineral metabolism, such that, for limited periods, mineral retention may occur coincident with nitrogen loss, but a complete final dependence of mineral retention on nitrogen metabolism is suggested by the work of Gregersen (Zeitschr. physiol. Chem. 71 (1911), 49-99) who found, in experiments with rats that, no matter how great the need for phosphorus, there was no phosphorus retention even from an overabundant intake, if this was furnished with a *nitrogen-free* ration.

In the light of this work it is not difficult to understand that, whatever the fundamental protein deficiency of corn, when an animal has been confined to a corn diet until the disturbance to nitrogen metabolism has become acute, we need not look for marked improvement from the giving of mineral nutrients, especially in an inorganic form.

From a practical point of view only those nutritive deficiencies of corn are of importance which are still manifest in the mixed rations in which corn is used. Successful farmers long since ceased feeding corn by itself to any animal, except under such conditions as allow the animal to pick up for himself in other foods those nutrients in which corn is deficient.

We all know that for practical feeding purposes the protein of corn is deficient in amount. We have also been shown that zein, the principal, but by no means the only protein in corn is, *by itself* an incomplete food, in the sense of being unable to sustain growth in rats, but we have no evidence that corn possesses protein deficiencies which remain manifest in the practical mixed rations in which we use corn.

These balance experiments show that the mineral deficiencies of corn are also to a large extent characteristic of the practical mixed grain rations in which many successful farmers use corn for hogs. It is true that in these experiments our periods were short, though they were longer than in most such investigations. The five repeats, however, are thought to go a long way toward protecting us from fair criticism on the ground of insufficiency of evidence. In considering the desirability of longer collection periods and more data it may be enlightening to some of our readers to learn that this experiment represents a full year's work for four men.

SUMMARY

Five pigs from the same litter, were used in a metabolism experiment involving eight 10-day collection periods, separated by 7-day intervals.

The foods used were corn alone in Periods I and VII; corn supplemented by soy beans, linseed oil meal, wheat middlings, meat meal (digester tankage) and skim milk in Periods II to VI, and a ration of rice polish and wheat bran in Period VIII.

The most important result of this investigation is the demonstration of the unsatisfactory character of corn, wheat middlings, linseed oil meal, soy beans, wheat bran and rice polish as sources of calcium for growing swine. Rations composed of these foods will not maintain normal growth of bone. The bony framework determines the size of the animal, and has much to do with determining its strength.

These pigs stored *9 to 10 times as much* calcium from rations containing milk and meat meal as from *the best one* of the rations of grain alone. These results emphasize the importance not so much of milk and of tankage as of *pasture*, *forage crops* and *dry roughage*, especially of leguminous plants, for these are our cheapest sources of those nutrients which the grain foods are shown to lack.

The important deficiencies of corn are considered to be calcium, phosphorus and nitrogen.

Phosphorus balances were positive, that is, phosphorus was stored on all rations, but phosphorus was insufficient for maximum growth in the ration of corn alone.

In the ration of rice polish and wheat bran, which contained 12 times as much magnesium as calcium, the excess of magnesium appeared to cause a loss of calcium from the animal. In the usual practical rations, however, this effect is not apparent.

These practical rations all contained an excess of acid over basic mineral elements. This excess acidity, however, did not appear to affect calcium retention, though we are not able certainly to distinguish between the effects of acid excess and calcium deficiency.

The ammonia of the urine was found to increase with the excess mineral acidity and the total protein of the ration.

One part of salt to 256 parts of other food seems to be more than sufficient for growing swine.

The balances of sodium and chlorine were largely controlled by the amount of water drunk.

There is an extensive metabolism of sodium apart from chlorine. The feces may contain an abundance of sodium but are nearly free from chlorine.

Magnesium tends to deflect the phosphorus excretion from urine to feces, and excessive phosphorus content of the ration limits the absorption of magnesium. With an intake of 2.17 gm. magnesium and 5.40 gm. phosphorus there was storage of magnesium; with an intake of 9.28 gm. magnesium and 20.71 gm. phosphorus there was loss of magnesium, combined with phosphorus, through the feces.

The potassium of these rations was more than enough in all cases. With the maximum intake, however, on the ration of wheat bran and rice polish, there was a loss of potassium, apparently through an excretion of previously stored excess.

The urinary potassium varies inversely as the retention.

Nitrogen and sulphur balances were all positive.

Sodium, potassium, sulphur and chlorine were excreted in larger proportion in the urine than in the feces, while calcium, magnesium and phosphorus left the body more largely in the feces.

The digestibility of the starch of corn is increased by the feeding with it of soy beans, tankage and milk. Tankage and milk also increase the digestibility of the fat, and decrease the digestibility of the crude fiber of corn.

Creatinin excretion in the urine was shown to be entirely independent of the food, and to vary among the several individuals in the same order as live weight, and weight of dressed carcass, flesh, bones and blood.

TABLE I. Composition of Foods—Percent Fresh Basis.

Foods	Moisture	Protein (Nx6.25)	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
Corn (Period I)	10.425	9.074	72.349	4.048	2.841	1.263	0.365	0.027	0.013	0.113	0.153	0.065	0.271
" " II)	10.565	9.060	72.236	4.042	2.837	1.261	0.354	0.027	0.013	0.113	0.153	0.065	0.271
" " III)	10.500	9.066	72.288	4.045	2.839	1.262	0.354	0.027	0.013	0.113	0.153	0.065	0.271
" " IV)	11.110	9.005	71.796	4.017	2.820	1.253	0.352	0.027	0.013	0.112	0.152	0.065	0.269
" " V)	11.315	8.984	71.620	4.008	2.813	1.250	0.351	0.027	0.013	0.112	0.152	0.065	0.269
" " VI)	"	"	"	"	"	"	"	"	"	"	"	"	"
" " VII)	"	"	"	"	"	"	"	"	"	"	"	"	"
Soy beans	7.385	40.706	21.961	18.465	4.995	5.155	1.982	0.5692	0.20764	0.2358	0.4208	0.0331	0.635
Linseed oil meal	9.305	35.922	31.191	6.391	11.329	5.862	1.1101	0.256	0.366	0.493	0.413	0.086	0.713
Wheat middlings	10.915	18.859	54.921	5.203	5.977	4.125	1.022	0.166	0.096	0.383	0.234	0.026	0.877
Meat meal	9.500	58.302	3.236	9.193	4.339	15.430	0.544	1.656	2.934	0.144	0.605	2.432	1.619
Skim milk	90.410	3.211	5.520	0.177	.....	0.687	0.122	0.047	0.128	0.014	0.034	0.091	0.094
Rice polish	11.127	12.475	53.296	12.770	3.200	7.132	1.1370	0.1100	0.0267	0.6585	0.168	0.134	1.497
Wheat bran	10.020	15.750	55.300	4.260	8.620	6.060	1.320	0.201	0.125	0.531	0.267	0.090	1.110
Salt	0.000	......	......	.....	......	......	0.000	38.220	0.240	0.000	0.160	59.130	0.000

Composition of Foods—Dry Basis

Foods	Moisture	Protein (Nx6.25)	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
Corn	......	10.130	80.769	4.519	3.172	1.410	0.396	0.030	0.014	0.126	0.171	0.073	0.303
Soy beans	......	43.962	25.152	19.937	5.393	5.566	2.140	0.615	0.224	0.255	0.454	0.036	0.686
Linseed oil meal	......	39.607	34.392	7.047	12.491	6.463	1.224	0.282	0.403	0.544	0.455	0.095	0.786
Wheat middlings	......	21.170	61.650	5.841	6.709	4.630	1.147	0.186	0.108	0.430	0.263	0.029	0.984
Meat meal	......	64.422	3.576	10.158	4.794	17.050	0.601	1.830	3.242	0.159	0.669	2.687	1.789
Skim milk	......	33.493	57.498	1.841	.....	7.168	1.272	0.488	1.336	0.146	0.357	0.953	0.979
Rice polish	......	14.036	61.097	13.243	3.600	8.024	1.279	0.124	0.030	0.741	0.189	0.151	1.684
Wheat bran	......	17.500	61.460	4.730	9.580	6.730	1.460	0.223	0.139	0.590	0.297	0.100	1.230

TABLE II. Total Foods Consumed—Grams Fresh Basis.

Periods	Foods	Pig I	Pig II	Pig III	Pig IV	Pig V
I 12 days	Corn	16567	24862	20655	14720	22749
	Salt	64.968	97.500	81.000	57.724	89.211
II 10 days	Corn	10459	17266	14942	10973	14219
	Soy beans	2092	3453	2988	2195	2844
	Salt	49.219	81.250	70.313	51.641	66.914
III 10 days	Corn	13945	19257	17266	13281	15772
	Linseed oil meal	2789	3852	3453	2656	3154
	Salt	65.625	90.625	81.250	62.500	74.219
IV 10 days	Corn	10133	11713	12298	10442	10949
	Wheat middlings	7645	8836	9277	7878	8259
	Salt	69.719	80.586	84.609	71.842	75.324
V 10 days	Corn	14995	20393	18219	15448	16209
	Meat meal	1500	2039	1822	1545	1621
	Salt	64.688	87.969	78.593	66.640	69.922
VI 10 days	Corn	15599	19145	18687	13866	17113
	Skim milk	31751	38968	38036	28224	34833
	Salt	61.172	75.078	73.277	54.375	67.109
VII 10 days	Corn	15599	19145	18687	13866	17113
	Salt	61.172	75.078	73.281	54.375	67.109
VIII 10 days	Rice polish	11699	......	......	10399	11206
	Wheat bran	3900	......	......	3467	3735
	Salt	61.172	......	......	54.375	58.594

TABLE III. Total Foods Consumed—Grams Dry Matter

Periods	Foods	Pig I	Pig II	Pig III	Pig IV	Pig V
I	Corn	14839.9	22270.1	18501.7	13185.4	20377.4
	Salt	64.968	97.500	81.000	57.724	89.211
II	Corn	9354.0	15441.8	13363.4	9813.7	12716.8
	Soy beans	1937.5	3198.0	2767.3	2032.9	2634.0
	Salt	49.219	81.250	70.313	51.641	66.914
III	Corn	12480.8	17235.0	15453.1	11886.5	14115.9
	Linseed oil meal	2529.5	3493.6	3131.7	2408.9	2860.5
	Salt	65.625	90.625	81.250	62.500	74.219
IV	Corn	9007.2	10411.7	10931.7	9281.9	9732.6
	Wheat middlings	6810.5	7871.6	8264.4	7018.1	7357.5
	Salt	69.719	80.586	84.609	71.842	75.324
V	Corn	13298.3	18085.5	16157.5	13700.1	14375.0
	Meat meal	1357.5	1845.3	1649.0	1398.2	1467.0
	Salt	64.688	87.969	78.593	66.640	69.922
VI	Corn	13834.0	16978.7	16572.6	12297.1	15176.7
	Skim milk	3044.9	3737.0	3647.7	2706.7	3340.5
	Salt	61.172	75.078	73.277	54.375	67.109
VII	Corn	13834.0	16978.7	16572.6	12297.1	15176.7
	Salt	61.172	75.078	73.281	54.375	67.109
VIII	Rice polish	10397.3	....	....	9241.9	9959.1
	Wheat bran	3509.2	....	....	3119.6	3360.8
	Salt	61.172	....	....	54.375	58.594

TABLE IV. Total Food Constituents—Grams Dry Matter.

Period No.	Pig No.	Protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
I	1	1503.3	11986.0	670.6	470.7	209.2	58.768	29.283	2.234	18.698	25.480	49.246	44.965
	2	2256.0	17987.3	1006.4	706.4	314.0	88.190	43.946	3.352	28.060	38.238	73.909	67.478
	3	1874.2	14943.6	836.1	686.9	260.9	73.267	36.509	2.784	23.312	31.768	61.401	56.060
	4	1335.7	10649.7	595.8	418.2	185.9	52.214	26.018	1.985	16.614	22.639	43.757	39.952
	5	2064.2	16458.6	920.9	646.4	287.3	80.695	40.213	3.067	25.676	34.988	67.632	61.744
II	1	1799.2	8042.4	809.0	401.2	239.7	78.505	33.534	5.768	16.727	24.870	36.629	41.634
	2	2969.9	13276.6	1335.4	662.3	395.7	129.564	55.355	9.521	27.612	41.054	60.467	68.727
	3	2570.0	11489.5	1155.6	573.1	342.4	112.139	47.902	8.239	23.895	35.528	52.327	59.475
	4	1887.6	8437.7	848.8	420.9	251.6	82.366	35.183	6.052	17.549	26.093	38.431	43.682
	5	2445.9	10933.7	1099.8	545.5	325.9	106.727	45.589	7.841	22.740	33.811	49.797	56.601
III	1	2266.2	10950.5	742.3	711.9	339.5	80.385	35.959	12.099	29.486	32.956	50.318	57.699
	2	3129.6	15122.0	1025.0	983.1	468.8	111.013	49.660	16.710	40.723	45.513	69.488	79.680
	3	2805.8	13558.4	919.0	881.4	420.3	99.527	44.521	14.979	36.507	40.804	62.299	71.483
	4	2158.2	10429.3	707.0	677.9	323.3	76.556	34.247	11.522	28.081	31.386	47.921	54.950
	5	2562.8	12385.1	839.8	805.1	383.9	90.912	40.668	13.682	33.346	37.273	56.908	65.254
IV	1	2354.2	11473.7	804.8	742.6	442.3	113.785	42.018	8.783	40.634	33.428	49.775	94.244
	2	2721.1	13262.2	930.3	858.4	511.3	131.517	48.565	10.152	46.967	38.635	57.535	109.004
	3	2857.0	13924.4	976.7	901.3	436.7	138.063	50.990	10.659	49.311	40.563	60.406	114.445
	4	2426.0	11823.5	829.3	765.2	163.4	117.254	43.297	9.051	41.873	34.445	51.291	97.182
	5	2543.5	12406.8	869.6	802.3	171.3	122.932	45.384	9.490	43.900	36.114	53.778	101.888
V	1	2221.6	10789.4	738.9	486.9	419.0	60.820	53.555	46.027	18.924	31.926	84.434	64.580
	2	3020.9	14673.5	1004.7	662.2	569.6	82.709	72.817	62.568	25.722	43.412	114.801	87.811
	3	2699.1	13109.3	897.7	591.6	509.4	73.894	65.062	55.912	22.980	38.787	102.576	78.458
	4	2288 5	11115.4	761.1	501.6	431.6	62.655	55.167	47.408	19.485	32.888	86.975	66.525
	5	2401.3	11663.0	798.6	526.3	452.8	65.742	57.883	49.741	20.446	34.507	91.257	69.801
VI	1	2421.2	12924.4	681.3	438.8	413.4	93.514	42.389	42.764	21.877	34.624	75.288	71.727
	2	2971.5	15862.2	836.1	538.6	507.3	114.771	52.026	52.483	26.849	42.490	92.402	88.030
	3	2900.5	15482.9	816.1	525.7	495.2	112.026	50.779	51.229	26.207	41.478	90.190	85.926
	4	2152.2	11488.5	605.5	390.1	367.4	83.126	37.680	38.015	19.446	30.778	66.924	63.759
	5	2656.2	14178.8	747.3	481.4	453.4	102.591	46.504	46.915	24.000	37.985	82.596	78.688
VII	1	1401.4	11173.6	625.2	438.8	195.1	54.783	27.530	2.084	17.431	23.754	46.270	41.917
	2	1719.9	13713.5	767.3	538.7	239.3	67.236	33.789	2.557	21.393	29.154	56.789	51.446
	3	1678.8	13385.5	748.9	525.7	233.7	65.627	32.980	2.496	20.881	28.456	55.429	50.215
	4	1245.7	9932.2	555.7	390.1	173.4	48.696	24.471	1.852	15.494	21.115	41.129	37.260
	5	1537.4	12258.1	685.8	481.4	214.0	60.100	30.202	2.286	19.123	26.059	50.761	45.985
VIII	1	2073.5	8509.2	1542.9	710.5	1070.5	184.215	44.098	8.145	97.748	30.171	55.380	218.173
	4	1843.1	7563.8	1371.5	631.6	951.6	163.760	39.199	7.240	86.888	26.819	49.228	194.005
	5	1986.0	8150.2	1477.9	680.5	1025.8	176.446	42.239	7.801	93.626	28.899	53.046	209.049

TABLE V. Total Urinary Constituents—Grams.

Period No.	Pig No.	Total nitrogen	Ammonia nitrogen	Creatinin	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
II	1	152.120	16.486	8.278	33.101	9.350	0.752	2.109	12.330	31.332	10.892
	2	234.024	28.307	10.421	40.170	11.971	1.151	3.017	19.321	47.028	14.915
	3	209.996	22.086	10.277	61.958	17.861	0.967	2.456	17.743	40.631	13.789
	4	148.065	25.200	6.974	50.199	13.827	0.803	1.256	12.974	31.577	8.765
	5	189.716	21.809	8.827	54.038	9.663	0.940	2.254	15.701	37.444	12.088
III	1	194.972	18.842	11.933	44.003	20.519	0.957	4.869	12.394	40.880	10.809
	2	263.476	26.419	16.390	56.737	21.544	1.721	6.732	21.559	54.905	12.772
	3	254.500	23.987	14.561	55.743	25.704	1.055	6.126	18.065	52.780	14.175
	4	180.724	29.010	11.338	37.924	19.251	0.931	3.490	10.231	38.373	8.130
	5	221.947	22.680	12.959	44.351	22.609	0.776	4.290	18.119	44.556	11.678
IV	1	190.637	25.866	15.713	55.855	25.681	2.092	4.414	13.014	46.331	33.888
	2	196.557	33.559	21.701	58.293	18.432	1.964	5.925	16.820	52.170	35.369
	3	246.682	36.208	21.257	68.105	26.321	2.376	5.960	18.636	56.842	42.281
	4	191.380	42.661	14.053	62.686	19.658	1.461	4.805	20.450	47.473	38.458
	5	214.910	30.114	17.798	57.461	18.538	1.192	5.277	15.969	48.128	37.683
V	1	188.043	24.818	19.022	36.535	52.553	2.114	3.783	10.457	85.374	20.074
	2	288.410	49.470	23.500	48.300	54.216	2.925	3.917	9.582	110.078	23.946
	3	263.857	30.234	22.939	47.107	59.482	2.154	3.963	10.209	102.776	25.246
	4	192.528	45.822	17.025	38.516	50.145	2.053	2.495	16.047	88.039	17.463
	5	200.727	24.360	20.997	37.861	49.113	1.318	2.889	11.832	49.964	19.537
VI	1	201.734	19.741	20.565	72.654	31.871	1.702	4.789	13.875	68.614	24.387
	2	296.737	34.857	24.925	90.297	31.858	2.766	4.823	22.607	82.972	27.251
	3	305.631	22.083	23.290	91.549	39.772	1.978	5.062	20.275	83.367	29.491
	4	205.344	35.788	18.157	69.133	24.481	1.643	2.351	12.238	61.966	19.171
	5	254.890	21.801	22.501	79.137	28.380	1.225	3.969	19.083	30.069	24.571
VII	1	143.568	19.375	24.296	28.198	28.620	1.190	2.978	12.374	42.681	17.262
	2	157.498	26.683	29.670	27.167	24.005	1.785	2.995	14.809	50.547	15.433
	3	165.607	18.289	28.475	30.073	32.408	1.394	3.163	15.864	49.865	18.009
	4	130.905	32.735	20.699	27.161	21.506	1.347	2.154	13.325	36.727	15.266
	5	162.278	18.852	26.390	30.591	28.117	0.879	2.607	13.697	45.591	17.495
VIII	1	167.079	24.248	28.587	162.019	11.479	1.159	5.268	12.023	37.887	9.374
	4	140.118	41.243	24.164	140.529	12.380	1.324	3.734	8.116	38.802	7.543
	5	168.537	22.909	28.984	149.298	13.426	0.833	4.092	9.928	34.574	8.962

TABLE VI. Total Weight of Feces—Grams as Sampled*

Pig No.	Period I	Period II	Period III	Period IV	Period V	Period VI	Period VII	Period VIII
I	1794	3305	5884	8098	4564	3934	3592	9566
II	3000	7745	9418	10954	7324	5685	5631	....
III	2330	5557	6594	8962	6036	5105	4803	....
IV	1569	4025	5795	8315	5647	3828	3556	9971
V	2510	5383	6623	8635	5000	4616	4129	9484

*The feces from Period I were dried in an air oven at 50° and sampled dry; all others were refrigerated and were then sampled moist.

TABLE VII. Feces Constituents—Percent, As Sampled.

Period No.	Pig No.	Total protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen	Metabolic nitrogen	Metabolic protein	Indigestible protein
1	1	16.625	51.833	12.911	6.047	8.711	1.120	0.205	0.423	0.955	0.255	0.011	1.869	2.660	1.609	10.056	6.569
	2	17.363	51.651	13.318	5.763	8.201	1.115	0.176	0.445	0.942	0.273	0.031	1.681	2.778	2.206	13.788	3.575
	3	16.975	51.271	13.637	5.825	8.616	1.028	0.402	0.471	0.980	0.250	0.009	1.824	2.716	1.805	11.281	5.694
	4	15.719	51.465	13.859	5.972	9.017	0.938	0.307	0.561	1.043	0.235	0.026	1.869	2.515	1.604	10.025	5.694
	5	17.425	49.939	13.776	5.980	8.647	1.092	0.221	0.407	0.975	0.259	0.031	1.755	2.788	1.803	11.269	6.156
2	1	9.306	16.388	6.033	4.721	4.036	0.487	0.114	0.230	0.457	0.147	0.005	0.801	1.489	0.911	5.694	3.612
	2	8.613	10.708	5.624	3.673	3.150	0.507	0.096	0.162	0.312	0.114	0.006	0.593	1.378	0.895	5.594	3.019
	3	7.169	13.405	4.893	4.137	3.337	0.508	0.067	0.163	0.368	0.107	0.004	0.689	1.147	0.760	4.750	2.419
	4	8.525	14.122	4.504	4.356	3.210	0.395	0.159	0.183	0.390	0.124	0.005	0.731	1.364	0.882	5.513	3.012
	5	8.506	12.388	6.265	4.395	3.419	0.538	0.070	0.156	0.368	0.120	0.005	0.670	1.361	0.864	5.400	3.106
3	1	7.825	15.747	5.554	6.913	4.229	0.465	0.129	0.137	0.474	0.129	0.008	0.772	1.252	0.724	4.525	3.300
	2	6.763	13.412	4.111	5.668	3.469	0.435	0.115	0.123	0.375	0.107	0.005	0.641	1.082	0.660	4.125	2.638
	3	6.788	15.436	4.862	7.085	4.133	0.464	0.102	0.137	0.474	0.120	0.003	0.778	1.086	0.597	3.731	3.057
	4	7.050	15.305	4.218	6.077	3.914	0.411	0.114	0.153	0.435	0.120	0.006	0.746	1.128	0.716	4.475	2.575
	5	6.325	15.043	4.449	6.522	4.146	0.523	0.093	0.143	0.453	0.126	0.010	0.750	1.172	0.757	4.731	2.594
4	1	5.513	15.388	2.937	5.876	3.275	0.502	0.166	0.065	0.432	0.105	0.006	0.685	0.882	0.577	3.606	1.907
	2	5.381	14.084	2.548	5.073	3.021	0.495	0.108	0.069	0.362	0.096	0.029	0.572	0.861	0.587	3.669	1.712
	3	5.313	16.153	3.876	6.553	3.561	0.594	0.050	0.067	0.488	0.105	0.015	0.689	0.850	0.546	3.413	1.900
	4	5.169	15.361	2.499	5.894	3.160	0.424	0.133	0.075	0.430	0.007	0.008	0.579	0.827	0.528	3.300	1.869
	5	4.906	15.149	2.704	6.113	3.268	0.497	0.122	0.093	0.445	0.097	0.016	0.603	0.785	0.502	3.138	1.768
5	1	10.681	15.543	3.401	5.406	3.751	0.222	0.204	0.301	0.342	0.180	0.006	0.606	1.709	0.955	5.969	4.712
	2	10.731	13.450	3.613	4.763	3.695	0.303	0.184	0.258	0.306	0.174	0.007	0.604	1.717	1.093	6.831	3.900
	3	10.994	14.650	3.103	5.519	3.730	0.288	0.158	0.320	0.347	0.183	0.005	0.609	1.759	0.952	5.950	5.044
	4	10.056	13.655	2.819	4.957	3.607	0.252	0.200	0.305	0.320	0.170	0.006	0.609	1.609	0.918	5.738	4.318
	5	10.675	14.994	3.239	5.635	4.025	0.290	0.187	0.353	0.367	0.190	0.007	0.637	1.708	0.996	6.225	4.450
6	1	7.244	19.895	5.188	4.645	3.661	0.335	0.200	0.284	0.410	0.112	0.003	0.709	1.159	0.717	4.481	2.763
	2	6.344	17.335	4.085	3.994	3.547	0.368	0.170	0.307	0.361	0.100	0.002	0.705	1.015	0.694	4.338	2.006
	3	5.906	16.001	4.302	4.150	3.506	0.356	0.134	0.282	0.387	0.090	0.002	0.714	0.945	0.579	3.619	2.287
	4	6.419	16.600	4.054	4.250	3.743	0.287	0.190	0.318	0.412	0.101	0.002	0.765	1.027	0.637	3.981	2.438
	5	7.144	15.949	4.747	3.863	3.807	0.375	0.132	0.294	0.409	0.118	0.004	0.742	1.143	0.700	4.375	2.769
7	1	5.893	17.441	5.833	4.360	3.397	0.452	0.096	0.120	0.423	0.098	0.005	0.677	0.943	0.512	3.200	2.693
	2	6.063	15.512	5.250	3.856	3.094	0.440	0.132	0.113	0.354	0.092	0.008	0.616	0.970	0.663	4.144	1.919
	3	5.450	16.686	5.387	4.398	3.231	0.422	0.111	0.117	0.401	0.088	0.005	0.649	0.872	0.374	2.338	3.112
	4	5.281	17.538	5.051	4.524	3.227	0.383	0.156	0.132	0.405	0.067	0.007	0.623	0.845	0.494	3.088	2.193
	5	5.831	17.454	5.777	4.420	3.435	0.459	0.119	0.122	0.426	0.101	0.010	0.673	0.933	0.592	3.700	2.131
8	1	4.506	11.592	3.086	5.727	6.781	0.416	0.152	0.111	1.046	0.086	0.006	1.588	0.721	0.413	2.581	1.925
	4	4.206	10.713	2.978	4.346	6.245	0.405	0.106	0.123	0.902	0.080	0.005	1.455	0.673	0.419	2.619	1.587
	5	4.038	12.804	3.148	4.708	6.871	0.486	0.075	0.126	1.027	0.086	0.007	1.589	0.646	0.416	2.600	1.438

TABLE VIII. Total Feces Constituents—Grams

Period No.	Pig No.	Total weight feces	Indigestible protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen	Total protein	Metabolic protein
I	1	1794	117.848	929.884	231.623	108.483	156.275	20.093	3.678	7.589	17.133	4.575	.197	33.530	47.720	298.252	180.405
	2	3000	107.250	1549.530	399.540	172.590	246.030	33.450	5.280	13.350	28.260	8.190	.930	50.430	83.340	520.899	413.640
	3	2330	132.670	1194.614	317.742	135.723	200.753	23.952	9.367	10.974	22.834	5.825	.210	42.499	63.283	395.518	262.847
	4	1569	89.339	807.486	217.428	93.701	141.477	14.717	4.817	8.802	16.365	3.687	.408	29.325	39.460	246.631	157.292
	5	2510	154.516	1253.469	345.778	150.098	217.040	27.409	5.547	10.216	24.473	6.501	.778	44.051	69.979	437.368	282.852
II	1	3305	119.377	541.623	199.891	156.029	133.390	16.095	3.768	7.602	15.104	4.858	.165	26.473	49.211	307.563	188.187
	2	7745	233.822	829.335	435.579	284.474	243.968	39.267	7.435	12.547	24.164	8.829	.465	45.928	106.726	667.077	433.255
	3	5557	134.424	744.916	271.904	229.893	185.437	28.230	4.835	9.058	20.450	5.946	.222	38.288	63.739	398.381	263.958
	4	4025	121.233	568.411	181.286	175.329	129.203	15.899	6.400	7.366	15.698	4.991	.201	29.423	54.901	343.131	221.898
	5	5383	167.196	666.846	337.245	236.583	184.045	28.961	3.768	8.397	19.702	6.460	.269	36.068	73.263	457.878	290.682
III	1	5384	177.672	847.818	299.027	372.196	227.689	25.036	6.945	7.376	25.520	6.945	.431	41.564	67.408	421.298	243.626
	2	9418	248.447	1263.142	387.174	533.812	326.710	40.968	10.831	11.584	35.318	10.077	.471	60.369	101.903	636.939	388.493
	3	6594	201.579	1017.850	320.600	467.185	272.530	30.596	6.726	9.034	31.256	7.913	.198	51.301	71.611	447.601	246.022
	4	5795	149.221	886.925	244.433	352.162	226.816	23.817	6.606	8.866	25.208	6.954	.348	43.231	65.368	408.548	259.326
	5	6623	171.801	996.298	294.657	431.952	274.590	34.638	6.159	9.471	30.002	8.345	.662	49.673	77.622	485.135	313.334
IV	1	8098	154.429	1246.120	237.838	475.838	265.210	40.652	13.443	5.264	34.963	8.503	.486	51.422	71.424	446.443	292.014
	2	10954	187.532	1542.761	279.108	555.696	330.920	54.222	11.830	7.558	39.653	10.516	3.177	62.657	94.314	589.435	401.902
	3	8982	170.658	1450.862	303.232	588.590	319.849	53.353	4.491	7.814	43.832	9.431	1.347	61.886	76.347	477.214	306.556
	4	8315	155.407	1277.267	207.792	490.086	262.754	35.257	11.059	6.236	35.575	8.066	.499	48.144	68.765	429.802	274.395
	5	8635	152.607	1308.116	233.490	527.858	282.192	42.916	10.535	8.031	38.426	8.376	1.382	52.069	67.785	423.633	270.966
V	1	4564	215.056	709.383	155.222	246.730	171.196	10.132	9.311	13.738	15.609	8.215	.274	27.658	77.999	487.481	272.425
	2	7324	285.636	985.078	264.616	348.110	270.622	22.192	13.476	18.896	22.411	12.744	.513	44.237	125.753	785.938	500.302
	3	6086	306.978	891.599	188.849	335.886	227.008	17.528	9.616	19.475	21.118	11.137	.304	37.064	107.063	669.095	362.117
	4	5647	243.837	771.098	159.189	279.922	203.687	14.230	11.294	17.223	18.070	9.600	.339	34.390	90.860	567.862	324.025
	5	5000	222.500	749.760	161.950	281.750	201.250	14.500	9.350	17.650	18.350	9.500	.350	31.850	85.400	533.750	311.250
VI	1	3934	108.696	782.669	204.096	182.734	144.024	13.179	7.868	11.173	16.129	4.406	.118	27.892	45.595	284.979	176.283
	2	5685	114.041	985.495	232.232	227.059	201.647	20.807	9.665	17.453	20.523	5.685	.114	40.079	57.703	360.656	246.615
	3	5105	116.751	816.851	219.617	211.858	178.930	18.174	6.841	14.396	19.756	4.595	.102	36.450	48.242	301.501	184.750
	4	3828	93.327	635.448	155.187	162.690	143.282	10.986	7.273	12.173	15.771	3.866	.077	29.284	39.314	245.719	152.393
	5	4616	127.817	736.206	219.122	178.316	175.731	17.310	6.093	13.571	18.879	5.447	.185	34.251	52.761	329.767	201.950
VII	1	3592	96.733	626.481	209.521	156.611	122.020	16.236	3.448	4.310	15.194	3.520	.180	24.318	33.873	211.677	114.944
	2	5631	108.059	873.481	295.628	217.131	174.223	24.776	7.443	6.363	19.934	5.181	.440	34.687	54.621	341.408	233.349
	3	4803	149.469	801.429	258.738	211.236	155.185	20.269	5.331	5.690	19.260	4.227	.260	31.171	41.882	261.764	112.294
	4	3556	77.983	623.651	179.614	160.873	114.752	13.619	5.547	4.694	14.402	3.094	.249	22.154	30.048	187.792	109.809
	5	4129	87.989	720.676	238.532	182.502	141.831	18.952	4.914	5.037	17.590	4.170	.413	27.788	38.524	240.762	152.773
VIII	1	9566	184.146	1108.891	293.294	547.845	648.670	39.795	14.540	10.618	100.060	8.227	.574	151.908	68.971	431.044	246.898
	4	9971	158.240	1068.193	296.936	433.340	622.689	40.383	10.569	12.264	89.938	7.977	.499	145.078	67.105	419.380	261.140
	5	9484	136.380	1214.331	298.556	446.507	651.646	46.282	7.113	11.950	97.401	8.156	.664	150.701	61.267	382.964	246.584

TABLE IX. Coefficients of Digestibility of Foodstuffs With Swine

Period No.	Foodstuff	Pig No.	Protein	Nitrogen-free extract	Ether extract	Crude fiber
I	Corn meal	1	92.16	92.24	65.46	76.95
		2	95.25	91.39	60.30	75.57
		3	92.92	92.01	62.00	76.87
		4	93.31	92.42	63.51	77.59
		5	92.51	92.38	62.45	76.78
		Ave.	93.23	92.09	62.74	76.75
VII	Corn meal	1	93.10	94.39	66.49	64.31
		2	93.72	93.63	61.47	59.69
		3	91.10	94.01	65.45	59.82
		4	93.74	93.72	67.68	58.76
		5	94.28	94.12	65.22	62.09
		Ave.	93.19	93.97	65.26	60.93
Ave. I and VII	Corn meal	1	92.63	93.32	65.98	70.63
		2	94.49	92.51	60.89	67.63
		3	92.01	93.01	63.73	68.35
		4	93.53	93.07	65.60	68.18
		5	93.40	93.25	63.84	69.44
		Ave.	93.21	93.03	64.01	68.85
II	Soybeans	1	94.18	92.43	85.61	34.08
		2	89.50	113.04	74.49	27.00
		3	97.84	101.38	90.42	35.84
		4	93.63	96.26	92.91	30.41
		5	92.09	103.99	75.35	20.26
		Ave.	93.45	101.42	83.76	29.52
III	Linseed oil meal	1	91.56	79.95	39.90	19.01
		2	89.00	81.65	66.46	18.23
		3	93.83	86.50	69.49	20.24
		4	92.53	73.26	64.88	22.83
		5	93.17	76.96	68.31	17.41
		Ave.	92.02	79.66	61.81	19.54
IV	Wheat middlings	1	93.95	81.90	75.02	14.23
		2	92.23	81.19	79.32	15.02
		3	95.30	83.64	74.30	13.65
		4	93.63	82.49	84.50	15.80
		5	94.38	83.08	82.68	12.17
		Ave.	93.90	82.46	79.16	14.17
V	Meat meal	1	86.76	(116.72)	(135.71)	(—88.71)
		2	84.46	(265.19)	(129.36)	(—83.61)
		3	83.41	(134.94)	(145.37)	(—119.57)
		4	82.90	(91.47)	(137.87)	(—111.39)
		5	86.63	(164.78)	(148.96)	(—102.55)
		Ave.	84.83	(154.62)	(139.45)	(—101.15)
VI	Skim milk	1	99.47	(97.93)	(115.32)	(—)
		2	98.46	(101.94)	(198.63)	(—)
		3	101.42	(105.66)	(177.39)	(—)
		4	98.60	(103.40)	(172.24)	(—)
		5	97.64	(104.75)	(146.93)	(—)
		Ave.	99.12	(102.74)	(162.10)	(—)

TABLE X. Average Daily Mineral Intake with Balance of Acid and Basic Elements—Grams

Period and Food	Pig No.	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Excess acid (c. c. normal sol.)	Ammonia nitrogen in urine
I Corn Salt	I	4.897	2.440	0.186	1.558	2.123	4.104	3.747	.....	1.712
	II	7.349	3.662	0.279	2.338	3.187	6.159	5.623	.....	2.599
	III	6.105	3.042	0.232	1.942	2.647	5.117	4.672	.....	1.954
	IV	4.351	2.168	0.165	1.384	1.887	3.646	3.329	.....	2.637
	V	6.724	3.351	0.255	2.139	2.916	5.636	5.145	.....	1.848
	Ave.	5.885	2.933	0.223	1.872	2.548	4.932	4.503	145.8	2.150
II Corn Soybeans Salt	I	7.851	3.353	0.577	1.673	2.487	3.663	4.168	.....	1.649
	II	12.958	5.536	0.952	2.761	4.105	6.047	6.873	.....	2.831
	III	11.214	4.790	0.824	2.390	3.553	5.233	5.948	.....	2.209
	IV	8.237	3.518	0.605	1.755	2.609	3.843	4.368	.....	2.520
	V	10.673	4.559	0.784	2.274	3.381	4.980	5.660	.....	2.181
	Ave.	10.187	4.351	0.748	2.171	3.227	4.753	5.402	18.9	2.278
III Corn Linseed oil meal Salt	I	8.039	3.596	1.210	2.949	3.296	5.032	5.770	.....	1.884
	II	11.101	4.966	1.671	4.072	4.551	6.949	7.968	.....	2.642
	III	9.953	4.452	1.498	3.651	4.080	6.230	7.148	.....	2.399
	IV	7.656	3.425	1.152	2.808	3.139	4.792	5.495	.....	2.901
	V	9.091	4.067	1.368	3.335	3.727	5.691	6.525	.....	2.268
	Ave.	9.168	4.101	1.380	3.363	3.759	5.739	6.581	63.2	2.419
IV Corn Wheat middlings Salt	I	11.379	4.202	0.878	4.063	3.343	4.978	9.424	.....	2.587
	II	13.152	4.857	1.015	4.697	3.864	5.754	10.900	.....	3.356
	III	13.808	5.099	1.066	4.931	4.056	6.041	11.445	.....	3.621
	IV	11.725	4.330	0.905	4.187	3.445	5.129	9.718	.....	4.266
	V	12.293	4.538	0.949	4.390	3.611	5.378	10.189	.....	3.011
	Ave.	12.471	4.605	0.963	4.454	3.664	5.456	10.335	116.3	3.368
V Corn Meat meal Salt	I	6.082	5.356	4.603	1.892	3.193	8.443	6.468	.....	2.482
	II	8.271	7.282	6.257	2.572	4.341	11.480	8.781	.....	4.947
	III	7.389	6.506	5.591	2.298	3.879	10.258	7.846	.....	3.023
	IV	6.266	5.517	4.741	1.949	3.289	8.698	6.653	.....	4.582
	V	6.574	5.788	4.974	2.045	3.451	9.126	6.980	.....	2.436
	Ave.	6.916	6.090	5.233	2.151	3.631	9.601	7.344	92.2	3.494
VI Corn Skim milk Salt	I	9.351	4.239	4.276	2.188	3.462	7.529	7.173	.....	1.974
	II	11.477	5.203	5.248	2.685	4.249	9.240	8.803	.....	3.496
	III	11.203	5.078	5.123	2.621	4.148	9.019	8.593	.....	2.208
	IV	8.313	3.768	3.802	1.945	3.078	6.692	6.376	.....	3.579
	V	10.259	4.650	4.692	2.400	3.799	8.260	7.869	.....	2.180
	Ave.	10.121	4.588	4.628	2.368	3.747	8.148	7.763	81.0	2.685
VII Corn Salt	I	5.478	2.753	0.208	1.743	2.375	4.627	4.192	.....	1.938
	II	6.724	3.379	0.256	2.139	2.915	5.679	5.145	.....	2.668
	III	6.563	3.298	0.250	2.088	2.846	5.543	5.022	.....	1.829
	IV	4.870	2.447	0.185	1.549	2.112	4.113	3.726	.....	3.274
	V	6.010	3.020	0.229	1.912	2.606	5.076	4.599	.....	1.885
	Ave.	5.929	2.979	0.226	1.886	2.571	5.008	4.537	147.0	2.319
VIII Rice polish Wheat bran Salt	I	18.422	4.410	0.815	9.775	3.017	5.538	21.817	.....	2.425
	IV	16.376	3.920	0.724	8.869	2.682	4.923	19.401	.....	4.124
	V	17.645	4.224	0.780	9.363	2.890	5.306	20.905	.....	2.291
	Ave.	17.481	4.185	0.773	9.276	2.863	5.255	20.708	232.8	2.947

TABLE XI. Mineral Elements in Average Daily Rations Computed to Cubic Centimeters of Normal Solution.

Period No.	Average daily rations Grams, Fresh Basis	Potassium	Sodium	Calcium	Magnesium	Total base	Sulphur	Chlorine	Phosphorus	Total acid	Excess acid
I	Corn........ 1659.2 Salt........ 6.507	150.5	127.2	11.1	153.9	442.7	158.9	139.1	290.5	588.5	145.8
II	Corn........ 1357.2 Soy beans........ 271.4 Salt........ 6.387	260.5	188.7	37.3	178.5	665.0	201.3	134.1	348.5	683.9	18.9
III	Corn........ 1590.4 Linseed oil meal........ 318.1 Salt........ 7.484	234.5	177.9	68.8	276.6	757.8	234.5	161.9	424.6	821.0	63.2
IV	Corn........ 1110.7 Wheat middlings........ 837.9 Salt........ 7.642	319.0	199.7	48.0	366.3	933.0	228.6	153.9	666.8	1049.3	116.3
V	Corn........ 1705.3 Meat meal........ 170.5 Salt........ 7.356	176.9	264.2	261.0	176.9	879.0	226.5	270.9	473.8	971.2	92.2
VI	Corn........ 1688.2 Skim milk........ 3436.2 Salt........ 6.620	258.8	199.0	230.8	194.7	883.3	233.7	229.8	500.8	964.3	81.0
VII	Corn........ 1688.2 Salt........ 6.620	151.6	129.2	11.3	155.1	447.2	160.3	141.2	292.7	594.2	147.0
VIII	Rice polish........ 1110.1 Wheat bran........ 370.1 Salt........ 5.805	447.1	181.5	38.6	762.8	1430.0	178.6	148.2	1336.0	1662.8	232.8

TABLE XII. Relation of Magnesium to Calcium Metabolism

Period No.	Ca Retention Grams	Ca Intake Grams	Ratio of Ca : Mg intake*	Excess mineral acid per day (c. c. normal sol.)	Urinary ammonia per day (N) Grams
VIII	—0.498	0.773	0.0633	232.8	2.947
VII	—0.427	0.226	0.120	147.0	2.425
IV	+0.083	0.963	0.216	116.3	3.368
II	—0.243	0.748	0.344	18.9	2.278
III	+0.344	1.380	0.410	63.2	2.419
VI	+3.047	4.628	1.954	81.0	2.685
V	+3.282	5.233	2.432	92.2	3.494

*In terms of chemically equivalent amounts.

TABLE XIII. Slaughter Test—Animals Arranged in Order of Creatinin Elimination—Kg.

No. of animal	Live weight	Dressed carcass	Flesh	Blood	Bones	Hoofs	Heart	Lungs	Liver	Kidneys	Spleen	Brain
II	121.0	102.7	91.4	4.288	6.454	0.310	0.316	0.407	1.255	0.201	0.120	0.110
III	111.0	94.6	83.9	3.733	6.242	0.294	0.261	0.525	1.155	0.177	0.128	0.108
V	108.6	92.1	81.9	3.588	.....	0.284	0.299	0.449	1.062	0.184	0.121	0.111
I	94.0	78.7	70.1	3.275	5.394	0.214	0.247	0.355	1.005	0.160	0.093	0.115
IV	89.0	75.0	66.7	3.024	.....	0.252	0.280	0.419	1.124	0.165	0.096	0.104

TABLE XIV. PERIOD II: Average Daily Rations and Mineral Balances—Grams.

Pig No.	Approximate live weight Kg.	Average daily rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	43	Corn	1045.9	7.851	3.353	0.577	1.673	2.487	3.663	4.163	28.787
		Soy beans	209.2	3.310	0.935	0.075	0.211	1.233	3.133	1.089	15.212
		Salt	4.922	1.610	0.377	0.760	1.510	0.486	0.017	2.647	4.921
		Water	2967	+2.931	+2.041	−0.258	−0.048	+0.768	+0.513	+0.427	+8.654
II	64	Corn	1726.6	12.958	5.536	0.962	2.761	4.105	6.047	6.873	47.518
		Soy beans	345.3	4.017	1.197	0.115	0.302	1.932	4.703	1.492	23.402
		Salt	8.125	3.927	0.744	1.255	2.416	0.883	0.047	4.593	10.673
		Water	4019	+5.014	+3.595	−0.418	+0.043	+1.290	+1.297	+0.788	+13.443
III	55	Corn	1494.2	11.214	4.790	0.824	2.390	3.553	5.233	5.948	41.120
		Soy beans	298.8	6.196	1.786	0.097	0.246	1.774	4.063	1.379	21.000
		Salt	7.031	2.823	0.484	0.906	2.045	0.595	0.022	3.829	6.374
		Water	4074	+2.195	+2.520	−0.179	+0.099	+1.184	+1.148	+0.740	+13.746
IV	42	Corn	1097.3	8.237	3.518	0.605	1.755	2.609	3.843	4.368	30.201
		Soy beans	219.5	5.020	1.383	0.080	0.126	1.297	3.158	0.877	14.807
		Salt	5.164	1.590	0.640	0.737	1.570	0.499	0.020	2.942	5.490
		Water	3297	+1.627	+1.495	−0.212	+0.059	+0.813	+0.665	+0.549	+9.904
V	56	Corn	1421.9	10.673	4.559	0.784	2.274	3.381	4.980	5.660	39.134
		Soy beans	284.4	5.404	0.966	0.094	0.225	1.570	3.744	1.209	18.972
		Salt	6.691	2.896	0.377	0.840	1.970	0.646	0.027	3.607	7.326
		Water	2949	+2.373	+3.216	−0.150	+0.079	+1.165	+1.209	+0.844	+12.836

TABLE XV. PERIOD III: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily ration		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	51	Corn	1394.5	8.039	3.596	1.210	2.949	3.296	5.032	5.770	36.259
		Linseed oil meal	278.9	4.400	2.052	0.096	0.487	1.239	4.088	1.081	19.500
		Salt	6.563	2.504	0.695	0.738	2.552	0.695	0.043	4.156	6.741
		Water	5313	+1.135	+0.849	+0.376	−0.090	+1.362	+0.901	+0.533	+10.018
II	76	Corn	1925.7	11.101	4.966	1.671	4.072	4.551	6.949	7.968	50.073
		Linseed oil meal	385.2	5.674	2.154	0.172	0.673	2.156	5.491	1.278	26.348
		Salt	9.063	4.097	1.083	1.158	3.532	1.008	0.047	6.037	10.190
		Water	6053	+1.330	+1.729	+0.341	−0.133	+1.387	+1.411	+0.653	+13.535
III	66	Corn	1726.6	9.963	4.452	1.498	3.651	4.080	6.230	7.148	44.892
		Linseed oil meal	345.3	5.574	2.570	0.106	0.613	1.807	5.278	1.418	25.450
		Salt	8.125	3.060	0.673	0.903	3.126	0.791	0.020	5.130	7.161
		Water	5935	+1.319	+1.209	+0.489	−0.088	+1.482	+0.932	+0.600	+12.281
IV	59	Corn	1328.1	7.656	3.425	1.152	2.808	3.139	4.792	5.495	34.531
		Linseed oil meal	265.6	3.792	1.925	0.093	0.349	1.023	3.837	0.813	18.072
		Salt	6.250	2.382	0.661	0.887	2.521	0.695	0.035	4.323	6.537
		Water	5212	+1.482	+0.839	+0.172	−0.062	+1.421	+0.920	+0.359	+9.922
V	67	Corn	1577.2	9.091	4.067	1.368	3.335	3.727	5.691	6.525	41.004
		Linseed oil meal	315.4	4.435	2.261	0.078	0.429	1.812	4.456	1.168	22.195
		Salt	7.422	3.464	0.616	0.947	3.000	0.835	0.066	4.967	7.762
		Water	3721	+1.192	+1.190	+0.343	−0.094	+1.080	+1.169	+0.390	+11.047

TABLE XIV. PERIOD II: Average Daily Rations and Mineral Balances—Grams.

Pig No.	Approximate live weight Kg.	Average daily rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	43	Corn	1045.9	7.851	3.353	0.577	1.673	2.487	3.663	4.163	28.787
		Soy beans	209.2	3.310	0.935	0.075	0.211	1.233	3.133	1.089	15.212
		Salt	4.922	1.610	0.377	0.760	1.510	0.486	0.017	2.647	4.921
		Water	2967	+2.931	+2.041	−0.258	−0.048	+0.768	+0.513	+0.427	+8.654
II	64	Corn	1726.6	12.958	5.536	0.952	2.761	4.105	6.047	6.873	47.518
		Soy beans	345.3	4.017	1.197	0.115	0.302	1.932	4.703	1.492	23.402
		Salt	8.125	3.927	0.744	1.255	2.416	0.883	0.047	4.593	10.673
		Water	4019	+5.014	+3.595	−0.418	+0.043	+1.290	+1.297	+0.788	+13.443
III	55	Corn	1494.2	11.214	4.790	0.824	2.390	3.553	5.233	5.948	41.120
		Soy beans	298.8	6.196	1.786	0.097	0.246	1.774	4.063	1.379	21.000
		Salt	7.031	2.823	0.484	0.906	2.045	0.595	0.022	3.829	6.374
		Water	4074	+2.195	+2.520	−0.179	+0.099	+1.184	+1.148	+0.740	+13.746
IV	42	Corn	1097.3	8.237	3.518	0.605	1.755	2.609	3.843	4.368	30.201
		Soy beans	219.5	5.020	1.383	0.080	0.126	1.297	3.158	0.877	14.807
		Salt	5.164	1.590	0.640	0.737	1.570	0.499	0.020	2.942	5.490
		Water	3297	+1.627	+1.495	−0.212	+0.059	+0.813	+0.665	+0.549	+9.904
V	56	Corn	1421.9	10.673	4.559	0.784	2.274	3.381	4.980	5.660	39.134
		Soy beans	284.4	5.404	0.966	0.094	0.225	1.570	3.744	1.209	18.972
		Salt	6.691	2.896	0.377	0.840	1.970	0.646	0.027	3.607	7.326
		Water	2949	+2.373	+3.216	−0.150	+0.079	+1.165	+1.209	+0.844	+12.836

TABLE XV. PERIOD III: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily ration		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	51	Corn	1394.5	8.039	3.596	1.210	2.949	3.296	5.032	5.770	36.259
		Linseed oil meal	278.9	4.400	2.052	0.096	0.487	1.239	4.088	1.081	19.500
		Salt	6.563	2.504	0.695	0.738	2.552	0.695	0.043	4.156	6.741
		Water	5313	+1.135	+0.849	+0.376	−0.090	+1.362	+0.901	+0.533	+10.018
II	76	Corn	1925.7	11.101	4.966	1.671	4.072	4.551	6.949	7.968	50.073
		Linseed oil meal	385.2	5.674	2.154	0.172	0.673	2.156	5.491	1.278	26.348
		Salt	9.063	4.097	1.063	1.158	3.532	1.008	0.047	6.037	10.190
		Water	6053	+1.330	+1.729	+0.341	−0.133	+1.387	+1.411	+0.653	+13.535
III	66	Corn	1726.6	9.953	4.452	1.498	3.651	4.080	6.230	7.148	44.892
		Linseed oil meal	345.3	5.574	2.570	0.106	0.613	1.807	5.278	1.418	25.450
		Salt	8.125	3.060	0.673	0.903	3.126	0.791	0.020	5.130	7.161
		Water	5935	+1.319	+1.209	+0.489	−0.068	+1.482	+0.932	+0.600	+12.281
IV	59	Corn	1328.1	7.656	3.425	1.152	2.808	3.139	4.792	5.495	34.531
		Linseed oil meal	265.6	3.792	1.925	0.093	0.349	1.023	3.837	0.813	18.072
		Salt	6.250	2.382	0.661	0.887	2.521	0.695	0.035	4.323	6.537
		Water	5212	+1.482	+0.839	+0.172	−0.062	+1.421	+0.920	+0.359	+9.922
V	67	Corn	1577.2	9.091	4.067	1.368	3.335	3.727	5.691	6.525	41.004
		Linseed oil meal	315.4	4.435	2.261	0.078	0.429	1.812	4.456	1.168	22.195
		Salt	7.422	3.464	0.616	0.947	3.000	0.835	0.066	4.967	7.762
		Water	3721	+1.192	+1.190	+0.343	−0.094	+1.080	+1.169	+0.390	+11.047

TABLE XVI. PERIOD IV: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily ration	*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	60	Corn........................1013.3	11.379	4.202	0.878	4.063	3.343	4.978	9.424	37.667
		Wheat middlings........... 764.5	5.586	2.568	0.209	0.441	1.301	4.633	3.389	19.064
		Salt...... .... 6.972	4.065	1.344	0.526	3.498	0.850	0.049	5.142	7.142
		Water....... 5709	+1.728	+0.290	+0.143	+0.124	+1.192	+0.296	+0.893	+11.461
II	86	Corn............. ....1171.3	13.152	4.857	1.015	4.697	3.864	5.754	10.900	43.537
		Wheat middlings. 883.6	5.829	1.843	0.196	0.593	1.682	5.217	3.537	19.656
		Salt.............. .... 8.059	5.422	1.183	0.756	3.965	1.052	0.318	6.266	9.431
		Water..................... 4476	+1.901	+1.831	+0.063	+0.139	+1.130	+0.219	+1.097	+14.450
III	75	Corn................. .....1229.8	13.808	5.099	1.066	4.931	4.056	6.041	11.445	45.712
		Wheat middlings.. .... 927.7	6.811	2.632	0.238	0.596	1.864	5.684	4.228	24.668
		Salt 8.461	5.335	0.449	0.781	4.383	0.943	0.135	6.189	7.635
		Water..... 5416	+1.662	+2.018	+0.047	—0.048	+1.249	+0.222	+1.028	+13.409
IV.	57	Corn............. ....1044.2	11.725	4.330	0.905	4.187	3.445	5.129	9.718	38.816
		Wheat middlings........... 787.8	6.269	1.966	0.146	0.481	2.045	4.747	3.846	19.138
		Salt 7.184	3.526	1.106	0.624	3.558	0.807	0.050	4.814	6.877
		Water...................... 5727	+1.930	+1.258	+0.135	+0.148	+0.593	+0.332	+1.058	+12.801
V	75	Corn........................1094.9	12.293	4.538	0.949	4.390	3.611	5.378	10.189	40.696
		Wheat middlings........... 825.9	5.746	1.854	0.119	0.528	1.596	4.813	3.768	21.491
		Salt 7.532	4.292	1.054	0.803	3.843	0.838	0.138	5.209	6.779
		Water...................... 4044	+2.255	+1.630	+0.027	+0.019	+1.177	+0.427	+1.214	+12.426

TABLE XVII. PERIOD V: Average Daily Rations and Mineral Balances—Grams.

Pig No.	Approximate live weight Kg.	Average daily ration		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	68	Corn	1499.5	6.062	5.356	4.603	1.892	3.193	8.443	6.458	35.545
		Meat meal	150.0	3.654	5.255	0.211	0.378	1.046	8.537	2.007	18.804
		Salt	6.469	1.013	0.931	1.374	1.561	0.822	0.027	2.766	7.800
		Water	5828	+1.415	—0.830	+3.018	—0.047	+1.325	—0.121	+1.686	+8.941
II	94	Corn	2039.3	8.271	7.282	6.257	2.572	4.341	11.480	8.781	48.334
		Meat meal	203.9	4.830	5.422	0.293	0.392	0.958	11.008	2.396	28.841
		Salt	8.797	2.219	1.348	1.890	2.241	1.274	0.051	4.424	12.576
		Water	3534	+1.222	+0.512	+4.074	—0.061	+2.109	+0.421	+1.962	+6.918
III	83	Corn	1821.9	7.389	6.506	5.591	2.298	3.879	10.258	7.846	43.186
		Meat meal	182.2	4.711	5.948	0.215	0.396	1.021	10.278	2.525	26.386
		Salt	7.859	1.753	0.962	1.948	2.112	1.114	0.030	3.706	10.706
		Water	5156	+0.926	—0.404	+3.428	—0.210	+1.744	—0.050	+1.615	+6.094
IV	64	Corn	1544.8	6.266	5.517	4.741	1.949	3.289	8.698	6.653	36.616
		Meat meal	154.5	3.852	5.015	0.205	0.250	1.606	8.804	1.746	19.253
		Salt	6.664	1.423	1.129	1.722	1.807	0.960	0.034	3.439	9.086
		Water	6350	+0.991	—0.627	+2.814	—0.108	+0.724	—0.140	+1.468	+8.277
V	83	Corn	1620.9	6.574	5.788	4.974	2.045	3.451	9.126	6.980	38.420
		Meat meal	162.1	3.786	4.911	0.132	0.289	1.183	4.996	1.954	20.073
		Salt	6.992	1.450	0.935	1.765	1.836	0.950	0.035	3.186	8.540
		Water	2971	+1.338	—0.058	+3.077	—0.079	+1.318	+4.095	+1.841	+9.807

TABLE XVIII. PERIOD VI: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	75	Corn	1559.9	9.351	4.239	4.276	2.188	3.462	7.529	7.173	38.739
		Skim milk	3175.1	7.265	3.187	0.170	0.479	1.868	6.861	2.439	20.173
		Salt	6.117	1.318	0.787	1.117	1.613	0.441	0.012	2.789	4.560
		Water	3950	+0.768	+0.265	+2.989	+0.096	+1.633	+0.656	+1.945	+14.006
II	102	Corn	1914.5	11.477	5.203	5.248	2.685	4.249	9.240	8.803	47.544
		Skim milk	3896.8	9.030	3.186	0.277	0.482	2.261	8.297	2.725	29.674
		Salt	7.508	2.061	0.967	1.745	2.062	0.569	0.011	4.008	5.770
		Water	1100	+0.366	+1.050	+3.226	+0.151	+1.419	+0.932	+2.070	+12.100
III	91	Corn	1868.7	11.203	5.078	5.128	2.621	4.148	9.019	8.596	46.408
		Skim milk	3803.6	9.155	3.977	0.198	0.506	2.028	8.337	2.949	30.563
		Salt	7.328	1.817	0.684	1.440	1.976	0.464	0.010	3.645	4.824
		Water	3630	+0.231	+0.417	+3.485	+0.139	+1.656	+0.672	+1.999	+11.021
IV	71	Corn	1386.6	8.313	3.768	3.802	1.945	3.078	6.692	6.376	34.436
		Skim milk	2822.4	6.913	2.448	0.164	0.235	1.229	6.197	1.917	20.534
		Salt	5.438	1.099	0.727	1.217	1.577	0.387	0.008	2.928	3.931
		Water	3900	+0.301	+0.593	+2.421	+0.133	+1.462	+0.487	+1.531	+9.970
V	90	Corn	1711.3	10.259	4.650	4.692	2.400	3.799	8.260	7.869	42.499
		Skim milk	3483.3	7.914	2.838	0.123	0.397	.908	3.006	2.457	25.489
		Salt	6.711	1.781	0.609	1.357	1.888	0.545	0.019	3.425	5.276
		Water	880	+0.614	+1.203	+3.112	+0.115	+1.346	+5.235	+1.987	+11.734

TABLE XIX. PERIOD VII: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily rations	*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	83	Corn 1559.9	5.478	2.753	0.208	1.743	2.375	4.627	4.192	22.422
		Salt 6.117	2.820	2.862	0.119	0.298	1.237	4.268	1.726	14.357
		Water 5940	1.624	0.345	0.431	1.519	0.352	0.018	2.432	3.387
			+1.034	−0.454	−0.342	−0.074	+0.786	+0.341	+0.034	+4.678
II	110	Corn 1914.5	6.724	3.379	0.256	2.139	2.915	5.679	5.145	27.518
		Salt 7.508	2.717	2.401	0.179	0.300	1.481	5.055	1.543	15.750
		Water 4345	2.478	0.743	0.636	1.993	0.518	0.045	3.469	5.462
			+1.529	+0.235	−0.559	−0.154	+0.916	+0.579	+0.133	+6.306
III	99	Corn 1868.7	6.563	3.298	0.250	2.088	2.846	5.543	5.022	26.860
		Salt 7.328	3.007	3.241	0.139	0.316	1.586	4.987	1.801	16.561
		Water 6770	2.027	0.533	0.562	1.926	0.423	0.024	3.117	4.188
			+1.529	−0.476	−0.451	−0.154	+0.837	+0.532	+0.104	+6.111
IV	79	Corn 1386.6	4.870	2.447	0.185	1.549	2.112	4.113	3.726	19.931
		Salt 5.438	2.716	2.151	0.135	0.215	1.333	3.673	1.527	13.091
		Water 5900	1.362	0.555	0.469	1.440	0.309	0.025	2.215	3.005
			+0.792	−0.259	−0.419	−0.106	+0.470	+0.415	−0.016	+3.835
V	98	Corn 1711.3	6.010	3.020	0.229	1.912	2.606	5.076	4.599	24.598
		Salt 6.711	3.069	2.812	0.088	0.261	1.370	4.559	1.750	16.228
		Water 3710	1.885	0.491	0.504	1.759	0.417	0.041	2.779	3.852
			+1.056	−0.283	−0.363	−0.108	+0.819	+0.476	+0.070	+4.518

TABLE XX. PERIOD VIII: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	94	Rice polish	1169.9	18.422	4.410	0.815	9.775	3.017	5.538	21.817	33.176
		Wheat bran	390.0	16.202	1.148	0.116	0.527	1.202	3.789	00.937	16.708
		Salt	6.117	3.980	1.454	1.062	10.006	0.823	0.057	15.191	6.897
		Water	6470	−1.760	+1.808	−0.363	−0.758	+0.992	+1.692	+5.689	+9.571
IV	89	Rice polish	1039.9	16.376	3.920	0.724	8.689	2.682	4.923	19.401	29.489
		Wheat bran	346.7	14.063	1.238	0.132	0.373	0.812	3.880	00.754	14.012
		Salt	5.438	4.028	1.057	1.226	8.994	0.798	0.050	14.508	6.711
		Water	6835	−1.715	+1.625	−0.634	−0.678	+1.072	+0.993	+4.139	+8.766
V	109	Rice polish	1120.6	17.645	4.224	0.780	9.363	2.890	5.305	20.905	31.776
		Wheat bran	373.5	14.930	1.343	0.083	0.409	0.998	3.457	00.898	16.854
		Salt	5.854	4.628	0.711	1.195	9.740	0.816	0.066	15.070	6.127
		Water	5570	−1.913	+2.170	−0.498	−0.786	+1.061	+1.782	+4.937	+8.795

TABLE XXI. Daily Rations and Mineral Balances per Period—Average for Five Pigs—Grams

Period No.	Approximate live weight Kg.	Rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
II	58	Corn	1357.2	10.187	4.351	0.748	2.171	3.227	4.753	5.402	37.363
		Soybeans	271.4	4.789	1.253	0.092	0.222	1.561	3.760	1.209	18.679
		Salt	6.387	2.569	0.524	0.899	1.902	0.622	0.027	3.524	6.967
		Water	3461	+2.828	+2.573	−0.243	+0.046	+1.044	+0.966	+0.669	+11.717
III	64	Corn	1590.4	9.168	4.101	1.380	3.363	3.759	5.739	6.581	41.362
		Linseed oil meal	318.1	4.775	2.192	0.109	0.510	1.607	4.630	1.152	22.318
		Salt	7.485	3.101	0.746	0.927	2.946	0.805	0.042	4.923	7.678
		Water	5247	+1.292	+1.163	+0.344	−0.093	+1.346	+1.067	+0.507	+11.361
IV	71	Corn	1110.7	12.471	4.605	0.963	4.454	3.664	5.456	10.335	41.286
		Wheat middlings	837.9	6.048	2.173	0.182	0.528	1.698	5.019	3.754	20.808
		Salt	7.642	4.528	1.027	0.698	3.849	0.898	0.138	5.524	7.573
		Water	5074	+1.895	+1.405	+0.083	+0.076	+1.068	+0.299	+1.058	+12.909
V	78	Corn	1705.3	6.916	6.090	5.233	2.151	3.631	9.601	7.344	40.420
		Meat meal	170.5	4.167	5.310	0.211	0.341	1.163	8.725	2.125	22.671
		Salt	7.356	1.572	1.061	1.740	1.911	1.024	0.035	3.504	9.741
		Water	4768	+1.178	−0.281	+3.282	+0.101	+1.444	+0.841	+1.714	+8.007
VI	86	Corn	1688.2	10.121	4.588	4.628	2.368	3.747	8.148	7.763	41.925
		Skim milk	3436.2	8.055	3.127	0.186	0.420	1.763	6.540	2.497	25.287
		Salt	6.620	1.609	0.755	1.375	1.821	0.480	0.012	3.359	4.872
		Water	2692	+0.456	+0.706	+3.047	+0.127	+1.503	+1.596	+1.906	+11.766
VII	94	Corn	1688.2	5.929	2.979	0.225	1.886	2.571	5.008	4.537	24.266
		Salt	6.620	2.864	2.693	0.132	0.278	1.401	4.508	1.669	15.197
		Water	5733	1.877	0.533	0.520	1.727	0.404	0.031	2.802	3.979
				+1.188	−0.247	−0.427	−0.119	+0.766	+0.469	+0.065	+5.090
VIII	97	Rice polish	1110.1	17.481	4.185	0.773	9.276	2.863	5.255	20.708	31.480
		Wheat bran	370.1	15.062	1.243	0.110	0.436	1.002	3.709	0.863	15.858
		Salt	5.808	4.215	1.074	1.161	9.580	0.812	0.058	14.923	6.578
		Water	6292	−1.796	+1.868	−0.498	−0.741	+1.049	+1.489	+4.922	+9.044

TABLE XXII. Average Daily Intake of Mineral Elements and Partition of Outgo Between Urine and Feces—Urine and Feces Together Equal 100 Percent. Intake (upper figure) in Grams; Urine (middle figure) and Feces (lower figure) in Percent of Outgo.

Periods	Rations	*Potassium* Intake Urine Feces	*Sodium* Intake Urine Feces	*Calcium* Intake Urine Feces	*Magnesium* Intake Urine Feces	*Sulphur* Intake Urine Feces	*Chlorine* Intake Urine Feces	*Phosphorus* Intake Urine Feces
II	Corn; soy beans	10.187 66.2 33.8	4.021 70.7 29.3	0.748 9.3 90.7	2.171 10.4 89.6	3.227 71.6 28.4	4.763 99.4 0.6	5.402 25.5 74.5
III	Corn; linseed oil meal	9.168 61.5 38.5	4.101 87.3 12.7	1.380 10.4 89.6	3.368 14.6 85.4	3.759 66.2 33.8	5.739 99.1 0.9	6.581 18.8 81.2
IV	Corn; wheat middlings	12.471 57.4 42.6	4.605 67.5 32.5	0.963 20.7 79.3	4.454 12.0 88.0	3.664 65.4 34.6	5.456 97.4 2.6	10.336 40.5 59.5
V	Corn; meat meal	6.916 72.9 27.1	6.090 83.5 16.5	5.233 10.7 89.3	2.151 15.2 84.8	3.631 53.9 46.1	9.601 99.5 0.5	7.344 37.9 62.1
VI	Corn; milk	10.121 83.5 16.5	4.588 80.4 19.6	4.628 11.8 88.2	2.368 18.6 81.4	3.747 78.3 21.7	8.148 99.9 0.1	7.763 42.6 57.4
VII	Corn	5.929 60.9 39.1	2.979 83.5 16.5	0.226 20.3 79.7	1.886 13.9 86.1	2.571 77.8 22.2	5.008 99.3 0.7	4.537 37.7 62.3
VIII	Rice polish; wheat bran	17.481 78.1 21.9	4.186 53.8 46.2	0.773 8.7 91.3	9.276 4.35 95.65	2.863 55.1 44.9	5.255 98.4 1.6	20.708 5.5 94.5

TABLE XXIII: Proportionate Elimination and Retention of Mineral Elements. Averages from Five Individuals—Intake (upper figure) in Grams; Urine (second figure), Feces (third figure), and Retention (lower figure) in Percent of Intake.

Periods	Rations	*Potassium* Intake Urine Feces Retention	*Sodium* Intake Urine Feces Retention	*Calcium* Intake Urine Feces Retention	*Magnesium* Intake Urine Feces Retention	*Sulphur* Intake Urine Feces Retention	*Chlorine* Intake Urine Feces Retention	*Phosphorus* Intake Urine Feces Retention
II	Corn; soy beans	10.187 48.0 24.5 +27.5	4.351 28.8 12.0 +59.1	0.748 12.2 120.3 −32.5	2.171 10.2 87.9 +1.9	3.227 48.4 19.3 +32.3	4.753 79.1 0.6 +20.3	5.402 22.4 65.2 +12.4
III	Corn; linseed oil meal	9.168 52.0 32.5 +14.4	4.101 53.4 18.2 +28.3	1.380 7.9 67.2 +24.9	3.363 15.0 87.7 −2.8	3.759 42.7 21.4 +35.8	5.739 80.7 0.7 +18.6	6.581 17.4 74.9 +7.7
IV	Corn; wheat middlings	12.471 48.6 36.1 +15.3	4.605 47.2 22.3 +30.5	0.963 18.9 72.5 +8.6	4.454 11.8 86.4 +1.8	3.664 46.3 24.5 +29.1	5.456 91.9 3.5 +5.5	10.335 36.4 53.4 +10.3
V	Corn; meat meal	6.916 60.3 22.4 +17.4	6.090 87.2 17.4 −46.1	5.233 4.0 33.3 +62.7	2.151 15.9 88.8 −4.7	3.631 32.0 28.2 +29.8	9.601 90.8 0.4 +8.7	7.344 29.0 47.5 +23.5
VI	Corn; skim milk	10.121 79.7 15.7 +4.6	4.588 68.1 16.4 +15.4	4.628 4.0 29.7 +65.8	2.368 17.6 77.1 +5.4	3.747 47.1 12.8 +40.1	8.148 80.3 0.1 +19.5	7.763 32.1 43.2 +24.6
VII	Corn	5.929 48.9 31.4 +19.8	2.979 90.4 17.9 −8.3	0.296 58.4 230.0 −18.9	1.886 14.8 91.5 −6.3	2.571 54.5 15.7 +29.7	5.008 90.0 0.6 +9.4	4.537 37.2 61.5 +1.3
VIII	Rice polish; wheat bran	17.481 86.1 24.2 −10.3	4.186 29.7 25.7 +44.6	0.778 14.2 150.1 −64.4	9.276 4.7 103.3 −8.0	2.863 35.0 28.3 +36.2	5.255 70.6 0.1 +28.3	20.708 4.2 72.2 +23.7

THE HAMILTON COUNTY EXPERIMENT FARM

SECOND ANNUAL REPORT, FOR THE YEAR 1913

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., MAY, 1914

BULLETIN 272

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

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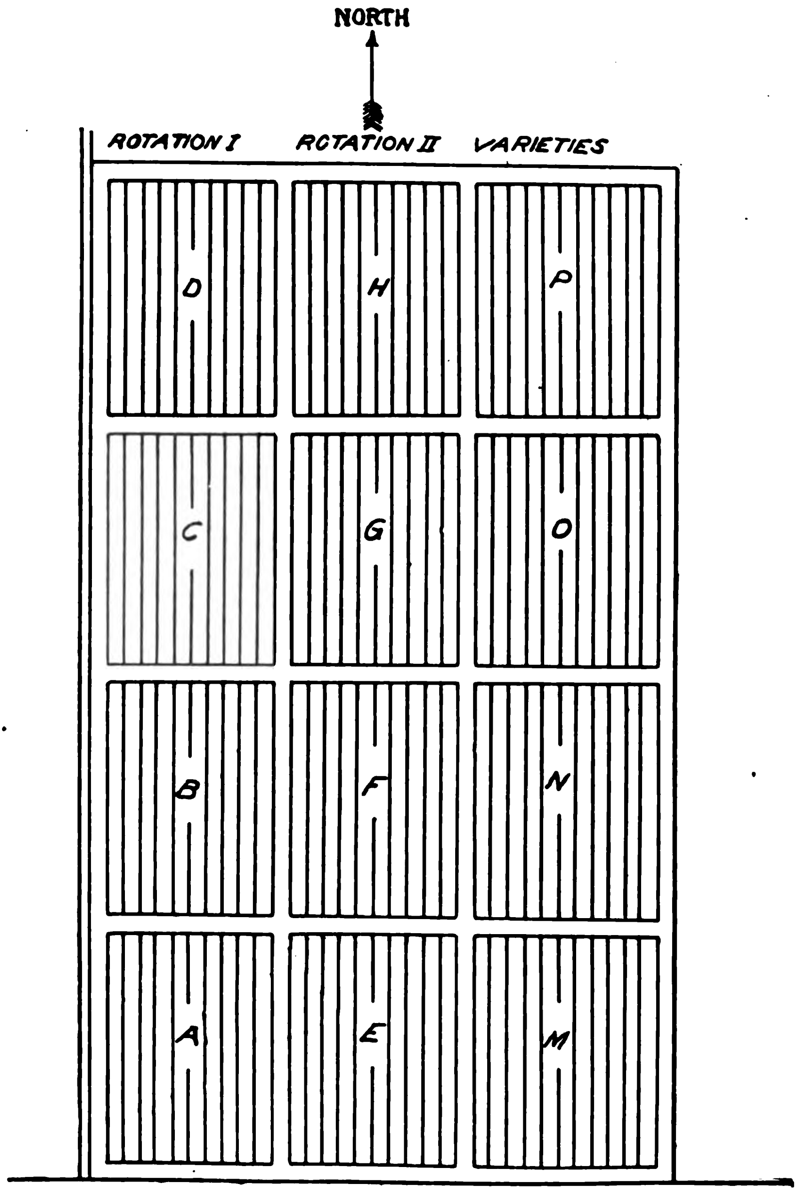
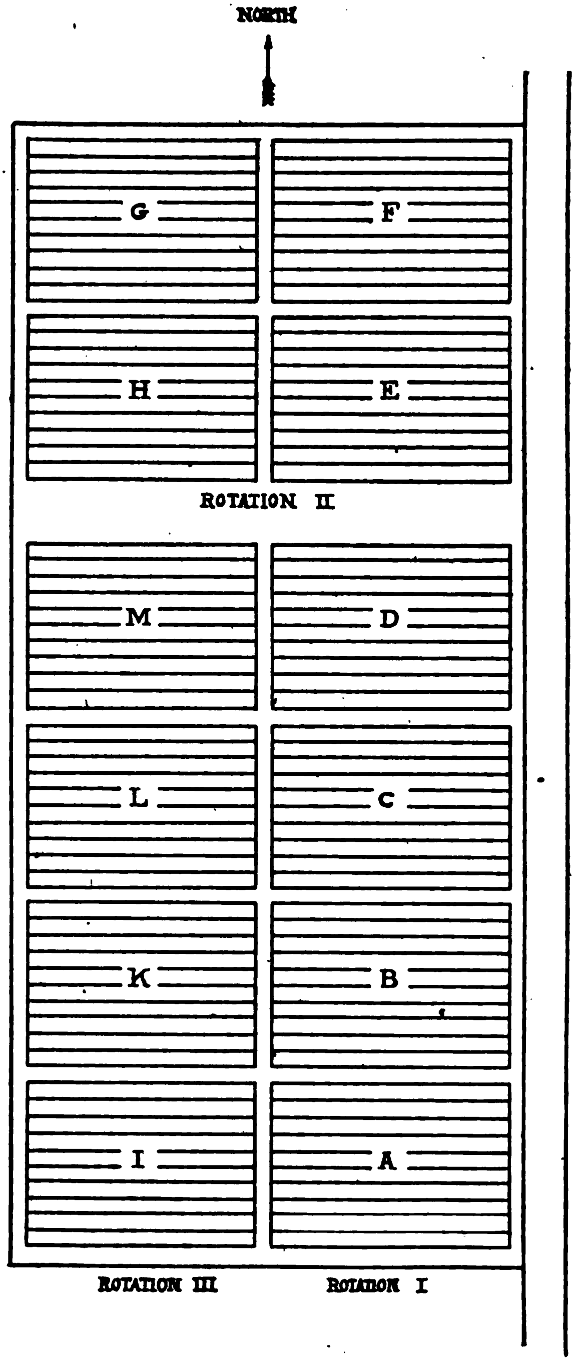


**Diagram: Arrangement of plots in cereal rotations
Hamilton County Experiment Farm**



The plots are 16 feet wide by 272.3 feet long, containing one-tenth acre each, and are separated by paths 3 feet wide.
Each block of 10 plots is numbered from south to north

Diagram I. Arrangement of plots in cereal rotations, Miami County Experiment Farm

TABLE I: Plan of fertilizing in cereal rotations, Miami county experiment farm.

Pounds of fertilizing materials per acre for each crop

Plot No.	Acid phosphate	Muriate potash	Nitrate soda	Powdered limestone	Acid phosphate	Muriate potash	Nitrate soda	Acid phosphate	Muriate potash	Nitrate soda
Rotation I: Corn, oats, wheat, clover										
	On Corn				On Oats			On Wheat		
1	..	..	..	......	...	..	..	...	..	..
2	200	..	..	......	100	..	..	200	..	..
3	200	50	..	......	100	20	..	200	20	..
4	...	..	..	......	...	..	..	...	..	..
5	200	50	50	......	100	20	30	200	20	80
6	200	50	50	4,000*	100	20	30	200	20	80
7	...	..	..	......	...	..	..	...	..	..
8	Manure, 8 tons		..	......	...	..	..	200	50	50
9	Manure, 8 tons, phosphated			......	...	..	..	200	50	50
10	...	..	..	......	...	..	..	...	..	..
Rotation II: Corn, soybeans, wheat, clover										
	On Corn				On Soybeans			On Wheat		
1	...	..	..	..	...	..	..	...	..	..
2	200	..	..	..	100	..	..	200	..	..
3	200	50	..	..	100	20	..	200	20	..
4	...	..	..	..	...	..	..	...	..	..
5	200	50	50	..	100	20	30	200	20	80
6	130	50	20	..	70	20	10	160	20	20
7	...	..	..	..	...	..	..	...	..	..
8	160	20	20	..	100	..	..	170	..	30
9	160	20	20	†	100	..	..	170	..	30
10	...	..	..	..	...	..	..	...	..	..
Rotation III: Corn, corn, oats, clover										
	On Corn 1st				On Corn 2nd			On Oats		
1	...	..	..	......	...	..	..	...	..	..
2	200	..	..	......	200	..	..	100	..	..
3	200	50	..	......	200	20	..	100	20	..
4	...	..	..	......	...	..	..	...	..	..
5	200	50	50	......	200	20	80	100	20	30
6	200	50	50	4,000*	200	20	80	100	20	30
7	...	..	..	......	...	..	..	...	..	..
8	Manure, 8 tons		..	......	200	50	50	...	..	..
9	Manure, 8 tons, phosphated*			......	200	50	50	...	..	..
10	...	..	..	......	...	..	..	...	..	..

*2,000 pounds in 1912. †Catch crop to follow corn.

Cropping in 1913:

Rotation I	Rotation II	Rotation III
Block D—Corn	Block E—Corn	Block J—Corn 1st
" C—Oats	" F—Soybeans	" M—Corn 2nd
" B—Wheat	" G—Wheat	" L—Oats

TABLE II: Plan of fertilizing in cereal rotations, Miami county experiment farm. Total fertilizing materials for one rotation; constituents and percentage composition

Plot No.	Total fertilizing materials for one rotation: Nitrate soda	Acid phosphate	Muriate potash	Total pounds	Fertilizing constituents contained: Ammonia	Phosphoric acid	Potash	Percentage composition: Ammonia	Phosphoric acid	Potash
Rotation I: Corn, oats, wheat, clover										
2	...	500	..	500	..	70	..	.	14	.
3	...	500	90	590	..	70	45	.	12	7
5	160	500	90	750	30	70	45	4	9.5	6
6	160	500	90	750	30	70	45	4	9.5	6
8	...	300	..	300	9.5	28	25	3	9	8
9	...	300	..	300	9.5	28	25	3	9	8
Rotation II: Corn, soybeans, wheat, clover										
2	...	500	..	500	..	70	..	.	14	.
3	...	500	90	590	..	70	45	.	12	7
5	160	500	90	750	30	70	45	4	9.5	6
6	50	360	90	500	9.5	50	45	2	10	9
8	50	430	20	500	9.5	60	10	2	12	2
9	50	430	20	500	9.5	60	10	2	12	2
Rotation III: Corn, corn, oats, clover										
2	...	500	..	500	..	70	..	.	14	.
3	...	500	90	590	..	70	45	.	12	7
5	160	500	90	750	30	70	45	4	9.5	6
6	160	500	90	750	30	70	45	4	9.5	6
8	50	200	50	300	9.5	28	25	3	9	8
9	50	200	50	300	9.5	28	25	3	9	8

In Rotations I and III the only difference in treatment between Plots 5 and 6 is in the lime applied on Plot 6 to the corn crop.

In Rotations II and III the variation between Plots 8 and 9 is in the treatment of the manure on the corn crop.

TABLE III, Part 1: Fertilizers and manure on CORN. Miami County Experiment Farm.

Plot No.	Treatment per acre	1913				3-year average				Plot No.
		Yield per acre		Increase per acre		Yield per acre		Increase per acre		
		Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	
	Rotation I (Corn-oats-wheat-clover) Block D									
1	None	25.29	1,700	....	....	41.62	2,330	.....	...	1
2	Acid phosphate, 200 lbs	41.43	1,600	11.38	*100	51.19	2,433	9.48	167	2
3	Acid phosphate, 200 lbs.; muriate potash, 50 lbs	44.00	2,100	9.19	400	54.02	2,740	12.23	537	3
4	None	39.57	1,700	....	....	41.88	2,140	.....	...	4
5	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	44.86	1,650	1.96	*217	50.98	2,427	8.90	249	5
6	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs; powdered limestone, 2,000 lbs.	49.86	2,350	3.62	317	54.12	2,657	11.84	441	6
7	None	49.57	2,200	....	....	42.48	2,253	.....	...	7
8	Untreated manure, 8 tons	64.43	2,450	6.50	*17	56.67	2,430	13.63	233	8
9	Phosphated manure, 8 tons	74.00	3,000	7.72	267	62.48	2,917	18.88	777	9
10	None	74.64	3,000	....	....	44.16	2,083	.....	...	10
	Average unfertilized yield	47.27	2,150	...	....	42.53	2,202	.....	...	
	Rotation II (Corn-soybeans-wheat-clover) Block E									
1	None	68.71	3,200	....	...	61.00	2,717	....	...	1
2	Acid phosphate, 200 lbs.	73.57	3,200	8.19	133	66.19	2,780	7.37	174	2
3	Acid phosphate, 200 lbs.; muriate potash, 50 lbs	72.29	3,600	10.25	667	67.57	3,050	10.93	556	3
4	None	58.71	2,800	....	...	54.47	2,383	....	...	4
5	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	58.86	3,150	3.48	433	56.81	2,733	4.16	368	5
6	Acid phosphate, 130 lbs.; muriate potash, 50 lbs.; nitrate soda, 20 lbs	53.29	2,800	1.25	167	55.10	2,580	4.28	232	6
7	None	48.71	2,550	....	...	49.00	2,330	....	...	7
8	Acid phosphate, 160 lbs.; muriate potash, 20 lbs.; nitrate soda, 20 lbs.**	55.29	2,600	9.01	233	56.95	2,580	9.68	323	8
9	Acid phosphate, 160 lbs.; muriate potash, 20 lbs.; nitrate soda, 20 lbs.**	50.43	2,560	6.57	377	51.19	2,660	5.65	477	9
10	None	41.43	2,000	....	...	43.81	2,110	....	...	10
	Average unfertilized yield	54.39	2,637	....	...	52.07	2,385	....	...	

*Decrease. **Plots 8 and 9, Rotation II, are treated alike, except that catch crops follow corn on Plot 9.

TABLE III, Part 2: Fertilizers and manure on CORN. Miami County Experiment Farm.

Plot No.	Treatment per acre	1913				3-year average				Plot No.
		Yield per acre		Increase per acre		Yield per acre		Increase per acre		
		Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	
	Rotation III (Corn-corn-wheat-clover) Corn first crop: Block I									
1	None	36.64	1,650	....	...	31.21	1,767	....	...	1
2	Acid phosphate, 200 lbs.	44.71	2,000	4.83	200	44.71	2,083	10.69	239	2
3	Acid phosphate, 200 lbs.; muriate potash, 50 lbs	52.71	2,150	9.58	200	52.09	2,433	15.26	511	3
4	None	46.37	2,100	....	...	39.65	2,000	....	...	4
5	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	55.50	2,750	9.37	683	52.41	2,483	12.73	420	5
6	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs.; powdered limestone, 2,000 lbs.	53.93	2,200	8.05	167	53.74	2,350	14.03	223	6
7	None	45.64	2,000	....	...	39.74	2,190	....	...	7
8	Untreated manure, 8 tons.	61.93	2,700	8.10	417	61.74	2,847	17.60	553	8
9	Phosphated manure, 8 tons.	72.71	2,800	10.69	233	62.95	2,850	14.42	453	9
10	None	70.21	2 850	....	...	52.93	2 500	....	...	10
	Average unfertilized yield	49.71	2 150	....	...	40.88	2 114	....	...	
	Rotation III (Corn-corn-wheat-clover) Corn second crop: Block M									
1	None	19.14	1,450	....	...	25.52	1,583	....	...	1
2	Acid phosphate, 200 lbs.	32.64	2,150	12.00	683	43.78	2,277	13.95	569	2
3	Acid phosphate, 200 lbs; muriate potash, 20 lbs.	31.57	1,950	9.43	467	47.67	2,463	13.52	631	3
4	None	23.64	1,500	....	...	38.45	1,957	....	...	4
5	Acid phosphate, 200 lbs.; muriate potash, 20 lbs.; nitrate soda; 80 lbs	29.57	1,950	5.43	317	48.00	2,517	10.53	533	5
6	Acid phosphate, 200 lbs.; muriate potash, 20 lbs.; nitrate soda, 80 lbs	31.36	2,450	6.72	683	48.83	2,703	12.34	693	6
7	None	26.14	1,900	....	...	35.52	2,037	....	...	7
8	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	32.00	2,700	2.26	483	50.76	2,863	15.75	746	8
9	Acid phosphate, 200 lbs.; muriate potash, 50 lbs.; nitrate soda, 50 lbs	35.80	3,000	1.47	467	50.70	2,907	16.20	708	9
10	None	38.93	2 850	....	...	33.98	2,280	....	...	10
	Average unfertilized yield	26.71	1 925	....	...	33.37	1 965	....	...	

TABLE IV: Fertilizers and manure on OATS. Miami County Experiment Farm.

Plot No.	Treatment per acre	1913				2-year average				Plot No.
		Yield per acre		Increase per acre		Yield per acre		Increase per acre		
		Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	Grain Bus.	Stover Lbs.	
	Rotation I (Corn-oats-wheat-clover) Block C									
1	None	47.66	3,200	....	...	51.01	3,145	....	...	1
2	Acid phosphate, 100 lbs.	48.75	3,040	2.81	202	53.94	3,248	2.02	338	2
3	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.	52.50	2,620	8.28	143	60.62	3,047	7.79	371	3
4	None	42.50	2,115	....	...	53.75	2,442	....	...	4
5	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.; nitrate soda, 30 lbs	53.55	2,217	11.62	192	60.63	2,448	8.17	157	5
6	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.; nitrate soda, 30 lbs	52.50	2,729	11.15	785	61.17	2,642	9.92	503	6
7	None	40.78	1,845	....	...	50.00	1,987	....	...	7
8	(Manured on corn)	44.84	2,115	5.93	360	44.84*	2,115*	5.93*	360*	8
9	(Manured on corn)	45.94	2,230	8.91	565	45.94*	2,230*	8.91*	565*	9
10	None	35.16	1,575	....	...	35.16*	1,575*	....	...	10
	Average unfertilized yield	41.53	2,184	....	...	47.48	2,287	....	...	
	Rotation III (Corn-corn-oats-clover) Block L									
1	None	34.37	1,800	.....	...	44.68	2,370	....	...	1
2	Acid phosphate, 100 lbs.	52.35	2,525	12.56	357	51.49	2,565	2.54	**39	2
3	Acid phosphate, 100 lbs.; muriate potash, 20 lbs	58.29	3,185	13.08	648	61.86	3,405	8.64	456	3
4	None	50.62	2,905	.....	...	57.49	3,072	....	...	4
5	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.; nitrate soda, 30 lbs	58.44	3,080	10.06	370	63.05	3,120	7.92	276	5
6	Acid phosphate, 100 lbs.; muriate potash, 20 lbs.; nitrate soda, 30 lbs	58.75	3,145	12.60	630	62.03	3,097	9.27	482	6
7	None	43.91	2,320	.....	...	50.39	2,387	....	...	7
8	(Manured on corn)	50.62	2,730	7.86	532	50.62*	2,730*	7.86*	532*	8
9	(Manured on corn)	53.12	2,875	11.50	798	53.11*	2,875*	11.50*	798*	9
10	None	40.47	1,955	.....	...	40.47	1,955*	....	...	10
	Average unfertilized yield	42.35	2,245	.....	...	48.26	2,446	....	...	

*One year. **Decrease.

TABLE V: Fertilizers on SOYBEANS. Miami County Experiment Farm, 1912 and 1913. Rotation II, Block F

Plot No.	Treatment per acre	Yield per acre 1912 Bus.	Yield per acre 1913 Bus.	Yield per acre Av. Bus.	Increase per acre 1912 Bus.	Increase per acre 1913 Bus.	Increase per acre Av. Bus.	Plot No.
1	None	20.00	18.33	19.16	....	....	....	1
2	Acid phosphate, 100 lbs.	21.00	18.08	19.54	0.22	0.80	0.51	2
3	Acid phosphate, 100 lbs.; Muriate potash, 20 lbs.	23.67	17.25	20.46	2.12	1.03	1.57	3
4	None	22.33	15.17	18.75	....	....	....	4
5	Acid phosphate, 100 lbs.; Muriate potash, 20 lbs.; Nitrate soda, 30 lbs.	26.00	14.75	20.37	1.95	*0.06	0.94	5
6	Acid phosphate, 70 lbs.; Muriate potash, 20 lbs.; Nitrate soda, 10 lbs.	23.50	12.83	18.16	*2.28	*1.61	*1.94	6
7	None	27.50	14.08	20.79	....	....	....	7
8	Acid phosphate, 100 lbs.	29.17	13.58	21.37	2.51	*0.81	0.85	8
9	Acid phosphate, 100 lbs.	27.17	13.83	20.50	1.33	*0.86	0.23	9
10	None	25.00	15.00	20.00	....	....	....	10
	Average unfertilized yield	23.71	15.65	19.68	....	....	....	

*Decrease.

TABLE VI: Fertilizers and manure on WHEAT. Miami County Experiment Farm, 1913

Plot No.	Treatment	Yield per acre Grain Bus.	Yield per acre Straw Lbs.	Increase per acre Grain Bus.	Increase per acre Straw Lbs.
	Rotation I (Corn-oats-wheat-clover) Block B				
1	None	29.17	3,625	....	....
2	Acid phosphate, 200 lbs.	33.00	3,920	4.05	440
3	Acid phosphate, 200 lbs.; muriate potash, 20 lbs.	35.67	4,210	6.95	875
4	None	28.50	3,190	....	....
5	Acid phos., 200 lbs.; mur. potash, 20 lbs.; nit. soda, 80 lbs.	30.00	3,550	6.44	877
6	Acid phos., 200 lbs.; mur. potash, 20 lbs.; nit. soda, 80 lbs.[1]	29.33	3,440	10.72	1,283
7	None	13.67	1,640	....	....
8	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs.[2]	28.58	3,335	9.02	1 035
9	Acid phos., 200 lbs.; mur. potash, 50 lbs., nit. soda, 50 lbs.[3]	30.58	3,765	5.14	805
10	None	31.33	3 620	....	....
	Average unfertilized yield	25.67	3,018	....	....
	Rotation II (Corn-soybeans-wheat-clover) Block G				
1	None	32.50	3,400	....	....
2	Acid phosphate, 200 lbs.	34.17	4,130	1.64	515
3	Acid phosphate, 200 lbs.; muriate potash, 20 lbs.	38.58	5,035	6.03	1,205
4	None	32.58	4,045	....	....
5	Acid phos., 200 lbs.; mur. potash, 20 lbs.; nit. soda, 80 lbs.	43.50	5,800	12.03	1,822
6	Acid phos., 160 lbs.; mur. potash, 20 lbs.; nit. soda, 20 lbs.	42.50	5,550	12.14	1,638
7	None	29.25	3,845	....	....
8	Acid phos., 170 lbs.; nitrate soda, 30 lbs.	38.08	5,115	10.47	1,588
9	Acid phos., 170 lbs.; nitrate soda, 30 lbs[4]	35.21	4,427	9.24	1,219
10	None	24.33	2 890	....	....
	Average unfertilized yield	29.67	3 545	....	....

[1]Fertilizers and limestone on corn. [2]Untreated manure on corn. [3]Phosphated manure on corn.
[4]Catch crop to follow corn.

TABLE VII: Fertilizers and manure on cereal crops grown in rotation, Miami County Experiment Farm: Average value of increase, cost of fertilizers and net gain per acre.

Plot No.	Treatment per acre Total fertilizers and manure for one 4-year rotation	Average increase per acre: Corn, Grain Bus.	Corn, Stover Lbs.	Oats or soybeans, Grain Bus.	Oats or soybeans, Straw Lbs.	Wheat, Grain Bus.	Wheat, Straw Lbs.	Total value of increase	Total cost of fertilizer	Net gain	Plot No.
	Rotation I (Corn-oats-wheat-clover)										
1	None	....	...	....	...	....	...	....	....	....	1
2	Acid phosphate, 500 lbs.	9.48	167	2.02	338	4.05	440	$ 9.07	$3.80	$5.27	2
3	Acid phosphate, 500 lbs.; muriate potash, 90 lbs	12.23	537	7.79	371	6.95	875	14.84	5.88	8.96	3
4	None	....	...	....	...	....	...	....	....	....	4
5	Acid phosphate, 500 lbs.; muriate potash, 90 lbs.; nitrate soda, 160 lbs	8.90	249	8.17	157	6.44	877	12.57	10.88	1.69	5
6	Acid phos., 500 lbs.; mur. potash, 90 lbs.; nit. soda, 160 lbs.; ground limestone, 2 tons	11.84	441	9.92	503	10.72	1,283	18.73	14.88	3.85	6
7	None	....	...	....	...	....	...	....	....	....	7
8	Acid phosphate, 200 lbs.; untreated manure, 8 tons	13.63	233	5.93	360	9.02	1,035	16.19	2.28	....	8
9	Acid phosphate, 200 lbs.; phosphated manure, 8 tons	18.88	777	8.91	565	5.14	805	16.87	4.71	....	9
10	None	....	...	....	...	....	...	....	....	..	10
	Rotation II (Corn-soybeans-wheat-clover)										
1	None	....	...	....	....	....	...	....	....	....	1
2	Acid phosphate, 500 lbs.	7.37	171	0.51	....	1.64	515	$ 6.05	$3.80	$2.25	2
3	Acid phosphate, 500 lbs.; muriate potash, 90 lbs	10.93	556	1.57	....	6.03	1,205	14.37	6.07	8.30	3
4	None	....	...	....	....	....	...	....	....	....	4
5	Acid phosphate, 500 lbs.; muriate potash, 90 lbs.; nitrate soda, 160 lbs.	4.16	368	0.94	....	12.03	1,822	15.54	10.87	4.67	5
6	Acid phosphate, 360 lbs.; muriate potash, 90 lbs.; nitrate soda, 50 lbs	4.28	232	*1.94	....	12.14	1,638	9.53	6.31	3.22	6
7	None	....	...	....	....	....	...	....	....	....	7
8	Acid phosphate, 430 lbs.; muriate potash, 20 lbs.; nitrate soda, 50 lbs	9.68	323	0.85	....	10.47	1,588	16.02	5.08	10.94	8
9	Acid phos., 430 lbs.; muriate potash, 20 lbs.; nitrate soda, 50 lbs. Catch crop**	5.65	477	0.23	....	9.24	1,219	12.05	10.08	1.97	9
10	None	....	...	....	....	....	....	....	....	....	10

*Decrease. **A catch crop of 1 bu. rye and 40 lbs. hairy vetch per acre, estimated cost, including labor of seeding, $5.00.

TABLE VII—Continued

Plot No.	Treatment per acre Total fertilizers and manure for one 4-year rotation	Average increase per acre: Corn, 1st year, Grain Bus.	Corn, 1st year, Stover Lbs.	Corn, 2nd year, Grain Bus.	Corn, 2nd year, Stover Lbs.	Oats, Grain Bus.	Oats, Straw Lbs.	Total value of increase	Cost of fertilizer	Net gain	Plot No.
	Rotation III (Corn-corn-oats-clover)										
1	None	.....	...	.....	...	....	...	.....	....	.....	1
2	Acid phosphate, 500 lbs.	10.69	239	13.95	569	2.54	*39	$11.79	$3.80	$7.99	2
3	Acid phosphate, 500 lbs.; muriate potash, 90 lbs.	15.26	511	13.52	631	8.64	456	16.27	5.08	11.19	3
4	None	.....	...	.....	...	....	...	.....	.....	.....	4
5	Acid phosphate, 500 lbs.; muriate potash, 90 lbs.; nitrate soda, 160 lbs.	12.73	420	10.53	533	7.92	276	13.38	10.88	2.50	5
6	Acid phos., 500 lbs.; muriate potash, 90 lbs.; nitrate soda, 160 lbs.; limestone, 2 tons.	14.03	223	12.34	693	9.27	482	15.18	14.88	.30	6
7	None	.....	...	.....	...	....	...	.....	.....	....	7
8	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs.; manure, 8 tons.	17.60	553	15.75	746	7.86	532	18.18	4.23	.....	8
9	Acid phos., 200 lbs.; mur. potash, 50 lbs.; nit. soda, 50 lbs.; phosphated manure, 8 tons	14.42	453	16.20	708	11.50	798	18.24	6.66	.....	9
10	None	.....	...	.....	...	....	...	.....	.....	.....	10

*Decrease.

In calculating the increase in these experiments it is assumed that the variations in natural productiveness between different plots are progressive; that is, that if Plots 1 and 4, untreated, yield 30 and 33 bushels respectively, the probability is that if Plots 2 and 3 had been left without treatment their yields would have been 31 and 32 bushels, respectively. Of course this assumption is not always correct, but experience has shown that in general the results arrived at in this way are more trustworthy than would be found by taking the general average of all the unfertilized plots as a basis of comparison.

The difference between the two methods of computation is illustrated by the outcome of the corn crop of 1913. In Block D, Rotation I, for example, the unfertilized yields range from 25.29 bushels on Plot 1 to 74.64 bushels on Plot 10. At first glance it would seem that such an irregularity in yield must completely nullify the experiment, and it certainly would, had there been left only one or two untreated plots, or were we to take the simple average of all the unfertilized plots, or of any two of them, as a guide. This point is brought out by Diagram II, which shows that the variation in unfertilized yield has been comparatively uniform, and that the method of calculation adopted and as represented by the lines A B gives results which may be accepted as at least much nearer the truth than would have been obtained by taking as a basis the general average, represented by the lines C D.

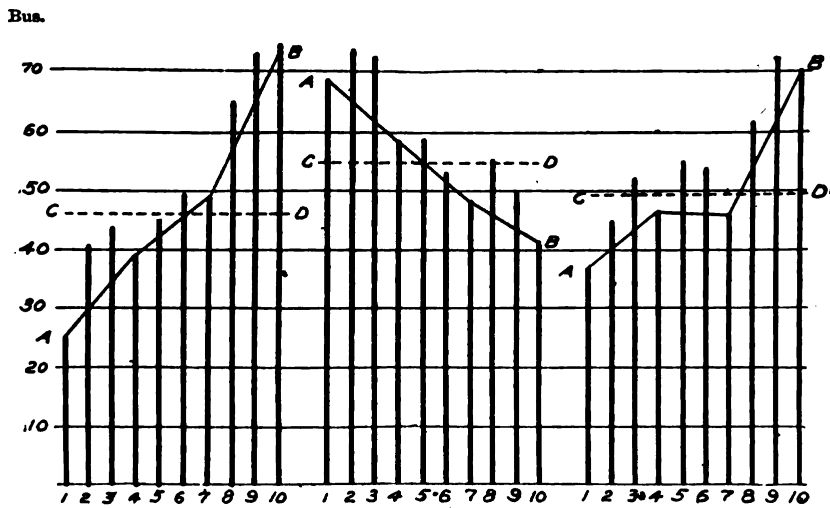


Diagram II: Illustrating method of computing increase.

One of the reasons for the variations in yield shown in this experiment is that the land itself is not as uniform as is desirable for this work, part of it being yellow clay and part black land. It was found so difficult to get enough of either kind of land in one body for this test that it was decided to depend upon the check plots for determining the variation in yield. In this connection it is interesting to compare the two blocks, D and E, which stand on opposite sides of a broad strip of low, black land, which was omitted from the test because of its character. It will be observed that the yield increases rapidly on both sides as this strip of land is approached. Miami County suffered from drought in 1913, and this low land was in better condition as to moisture than the higher land.

Past experience justifies the expectation that as this work progresses under uniform treatment the difference in yield due to superficial soil variations will be modified, and that the effect of the treatment will become more definite.

THE OUTCOME OF THE EXPERIMENTS

It is too early as yet to attempt to draw any but the most general conclusions from these experiments. The first rotation of four years is not yet completed, the clover crop being yet to come, and experience has shown that we may not only expect an increase in the hay crop from the fertilizers and manures which have been applied to the three preceding cereal crops, but that a considerable part of the effect of the treatment will be realized during the next rotation. For example,the average value of the increase of crops from a dressing of acid phosphate on crops grown in a 5-year rotation of corn, oats, wheat, clover and timothy, was $8.50 per acre for the first 5 years at Wooster and $14.12 at Strongsville, and for the second 5 years it was $17.37 at Wooster and $21.60 at Strongsville.

It seems safe to assume, however, that acid phosphate is producing a very profitable increase on all the crops in the three cereal rotations in progress at this farm, and that both total and net gains are increased where the acid phosphate is reenforced by muriate of potash, thus indicating that this land is deficient in both phosphorus and potassium.

When nitrate of soda has been added to the combination of acid phosphate and muriate of potash the calculated increase in the corn crop is found to be smaller in most cases than from those applications in which the nitrate was omitted. In the case of the oats and wheat crops, however, there is usually an increased yield following the addition of nitrate of soda to the fertilizer, although in no case

has the total increase in the three crops thus far grown in this rotation been sufficient to offset the additional cost of the fertilizer when nitrate of soda has been added, as shown by the general summary given in Table III. It must be remembered, however, that this summary is incomplete, as the clover crop is yet to be heard from.

In the case of the barnyard manure, as used in rotations I and III, an increase is found equivalent to about $14 for 8 tons of untreated manure at this stage of the work, with the probability that the clover crop will bring up the net gain to at least $2.00 per ton of manure. Thus far neither the reenforcement of the manure with acid phosphate nor the supplementing it with a complete fertilizer has produced sufficient increase to justify the additional cost, but it is quite too early to attempt to draw final conclusions. Referring again to the experiments at Wooster and Strongsville, we find that the increase from 8 tons of yard manure during three successive 5-year periods amounted to $12.02, $21.28, and $35.36 at Wooster, and to $12.56, $12.62 and $21.22 at Strongsville, the slower rate of increase at Strongsville being due to a less responsive soil and to an inferior quality of manure.

CONCLUSIONS

At the present stage of this work it seems evident that the soil of Miami County will respond very profitably to fertilizers containing phosphorus and potassium, but that nitrogen should be obtained by the careful saving of barnyard manure and the growing of clover, alfalfa and similar crops, rather than by its purchase in commercial fertilizers. For nitrate of soda is not only the most effective but the cheapest source of fertilizer nitrogen, and if it fails to produce a profit the farmer may be sure that the "ammonia" of the fertilizer sack will be used at a loss.

GROWING CORN CONTINUOUSLY ON THE SAME LAND

In bringing the several blocks in this experiment into their respective places in the rotation, corn has been grown for three years in succession on Block M. The unfertilized yields for the first and last year are given below, in comparison with the similar yields on other blocks where the corn followed clover or soybeans:

			Bushels per acre		
			1911		1913
Rotation	I	Block C	24.85	Block D	47.27
"	II	" G	38.14	" E	54.39
"	III	" L	20.57	" I	49.71
"	"	" M	22.86	" M	26.71

Corn has been grown continuously and in rotation for 20 years at Wooster, with the following yields on unfertilized land by 5-year periods:

	Bushels per acre			
	1st 5 years	2nd 5 years	3rd 5 years	4th 5 years
Continuous	26.26	23.73	17.20	8.44
Rotation	31.89	30.82	31.04	20.31

The falling off in yield in the rotation corn during the last 5 year period was largely due to injury from white grub. The continuous corn did not suffer from this insect.

EXPERIMENTS WITH TOBACCO

Table VIII gives the results of the experiments with fertilizers and manure on tobacco, and Table IX gives the outcome of a comparison of varieties made under the supervision of A. D. Selby, with the assistance of Henry M. Wachter and True Houser of the Southwestern Test farm at Germantown.

TABLE VIII: Fertilizers and manure on TOBACCO and WHEAT in tobacco-wheat-clover rotation. Miami County Experiment Farm. Yield and increase per acre.

Plot No.	Treatment per acre	Tobacco				Wheat, 1913			
		1913		2-year average		Yield		Increase	
		Yield Lbs.	Increase Lbs.	Yield Lbs.	Increase Lbs.	Grain Bus.	Straw Lbs.	Grain Bus.	Straw Lbs.
1	None	1,240	...	1,590	...	46.42	3,707	....	...
2	Acid phosphate, 480 lbs	1,390	27	1,730	128	39.33	3,195	*5.03	*507
3	Acid phosphate, 480 lbs. Muriate potash, 180 lbs.	1,630	143	1,820	206	40.75	3,475	*1.56	*222
4	None	1,610	...	1,625	...	40.25	3,692	....	...
5	Acid phosphate, 480 lbs. Muriate of potash, 180 lbs. Nitrate of soda, 240 lbs.	1,790	330	1,705	183	43.67	3,665	3.94	224
6	Acid phosphate, 480 lbs. Muriate of potash, 180 lbs. Nitrate of soda, 240 lbs. Ground limestone, 2,000 lbs.	1,770	460	1,870	452	41.33	3,410	2.13	219
7	None	1,160	...	1,315	...	38.67	2,940	....	...
8	Acid phosphate, 240 lbs. Muriate of potash, 90 lbs. Nitrate of soda, 120 lbs.	1,430	330	1,515	265	39.67	3,035	*.11	145
9	Acid phosphate, 400 lbs. Stable manure, 10 tons	1,440	400	1,452	268	37.33	3,030	*3.56	190
10	None	980	...	1,117	...	42.00	2,790	....	...
	Average unfertilized yield	1,247	...	1,411	...	41.83	3,282	....	...

*Decrease.

TABLE IX: Comparison of varieties of TOBACCO. Miami County Experiment Farm, 1913

Variety or selection	Yield per acre Lbs.	Increase per acre Lbs.
Zimmer Spanish (check)	1,640	...
81-4150	2,050	413
110-5012-6001	2,510	877
Zimmer Spanish (check)	1,630	...
170-3033	2,070	420
89-5017-No. 5	2,200	530
Zimmer Spanish (check)	1,690	...
307 hmp. 107	2,240	627
199-174-236	2,080	543
Zimmer Spanish (check)	1,460	...
Average Zimmer Spanish	1,605	...

VARIETY TESTING

CORN

In the variety testing of corn it is the aim to test the standard varieties adapted to the county. In 1913, eight varieties were grown, as reported in Table X. The comparative yield, as corrected by the check plots, is given in the third column. The Clarage stands slightly in the lead, with Reid second.

All but two of the varieties grown in 1913 were also grown in 1911. The two-year average yield is given in the fourth column. It will be noted that the Darke County Mammoth used upon the check plots stands first, with the Reid second. The check variety differs from that planted on Plot 10 in that it had been grown locally for two years previous. The latter was not as well acclimated.

TABLE X: Comparison of varieties of CORN. Miami County Experiment Farm.

Plot No.	Variety	1913 Actual yield per acre: Corn Bus.	1913 Actual yield per acre: Stover Lbs.	1913 Comparative yield Bus.	2-year average yield Bus.
1	Leaming	48.36	2,600	48.61	44.07
2	Check (Darke County Mammoth)	58.14	2,400	.....	.....
3	Clarage	59.57	1,550	59.91	47.69
4	White Cap	55.43	2,950	55.86	.....
5	Check	57.86	3,200	.....	.....
6	Cook's No. 75	57.57	2,850	57.29	48.17
7	Reid (Orcutt)	60.93	2,950	59.84	49.07
8	Check	60.29	3,150	.....	.....
9	Ohio 84 (Early Reid)	48.50	2,500	47.60	40.00
10	Darke County Mammoth (Station)	53.50	2,750	53.60	48.90
11	Check	57.29	3,350	.....	.....
12	Leaming (Scott)	47.43	2,700	48.53	.....
	Average yield of check plots	58.39	.....	.....	50.49

WHEAT

Two distinct variety tests of wheat were conducted in 1912-13. One set of 12 plots was grown after tobacco. The same variety of wheat—the Velvet Chaff—was used as check in each set. It is of interest to note that the checks average 6.05 bushels higher following tobacco. One other variety was the same in each test, viz: Gypsy Selection 6100, and it gives an increased yield of 7.44 bushels after tobacco. Similar results are secured in northern Ohio in growing wheat after potatoes. Better soil conditions with respect to moisture, nitrates and seed bed probably account for this result.

In the 12-plot test the Rudy, Gypsy Selection 6100 and Nigger lead, with but a small fraction of a bushel difference.

In the tobacco-wheat-clover test three pedigreed selections of wheat which the Experiment Station has developed in its head-row testing work at Wooster, are compared, side by side, with the bulk varieties from which they were selected. In each instance the pedigreed strain exceeds the original, and in the case of Poole Selection 6400 the margin is quite remarkable.

The Miami County wheat yields were exceptionally good in 1913. It should be stated that in 1912 only two varieties survived the winter, viz.; the Turkey Red and the Kharkof. These are unusually hardy Russian varieties which will endure more hardship than our American varieties, but do not usually yield as well in Ohio of a normal season.

The yields at Wooster for the year 1913 are recorded for comparison.

TABLE XI: Comparison of varieties of WHEAT. Actual and comparative yields per acre.

Plot No.	Variety	Miami county			Wooster
		Grain		Straw	Comparative 1913
		Actual	Comparative	Actual	
		Bus.	Bus.	Lbs.	Bus.
1	Nigger	44.67	42.94	5,820	34.26
2	Check (Velvet Chaff)	38.50	.....	4,190	.....
3	Gypsy Selection No. 6100	44.33	43.16	5,710	32.77
4	Mediterranean	39.08	38.47	5,655	28.91
5	Check	36.83	.....	5,105	.....
6	Rudy	42.92	43.22	4,225	33.10
7	Turkey Red	37.92	38.58	4,885	28.83
8	Check	35.75	.....	4,865	.....
9	Fultz Selection No. 6300	40.50	41.44	4,740	35.13
10	Goens	37.08	37.94	5,175	31.85
11	Check	36.00	.....	5,065	.....
12	Valley	41.33	42.10	5,950	29.50
	Average of checks	36.77	.....	4,806	29.55

TABLE XII: **Pedigreed wheat test.**

Plot No.	Variety	Miami County			Wooster
		Grain		Straw	Comparative 1913
		Actual	Comparative	Actual	
		Bus.	Bus.	Lbs.	Bus.
1	Check (Velvet Chaff)	42.67	.....	6,240	.....
2	Gypsy	46.33	45.37	6,810	29.04
3	Gypsy Selection 6100	52.67	50.60	7,240	32.77
4	Check	46.00	.....	6,890	.....
5	Poole	46.08	44.57	6,135	34.90
6	Poole Selection 6400	55.33	55.49	5,230	40.45
7	Check	41.00	.....	5,680	.....
8	Fultz	40.00	41.60	5,150	31.53
9	Fultz Selection 8106	41.50	42.88	5,160	33.74
10	Check	41.67	.....	5,800	.....
	Average checks	42.82	.....	. ...	29.55

OATS

Seven varieties of oats, Oderbrucker barley and emmer (sometimes called speltz) are included in the oats variety test. The Big Four variety leads, both in the 1913 test and in the 2-year average, while the Swedish Select and Silver Mine are close seconds.

Emmer gives a remarkable yield in 1913—much better than in 1912. In comparing emmer with barley and oats it should be stated that the yield is recorded at 32 lbs. per bushel for both oats and emmer, and 48 lbs. for the barley. Emmer is supposed to weigh more than oats, but at Wooster it has tested about the same.

The yield of the same varieties for the last six years at Wooster is included for comparison.

TABLE XIII: **Comparison of varieties of OATS. Miami County Experiment Farm.**

Variety	Comparative yields			
	1913		2-yr. average Miami	6-yr. average Wooster
	Grain	Straw		
	Bus.	Lbs.	Bus.	Bus.
Ohio 7009 (Sixty Day)	44 14	1,730	59.17	66.52
Ohio 6203 (Siberian)	60.75	4,270	67.95	69.55
Swedish Select	61.12	3,480	69.85	56.70
Big Four	62.99	3,830	70.58	65.50
Silver Mine	61.0	2,705	69.41	65.42
Ohio 6222 (Improved American)	51.87	2,990	.....	66.18
Emmer	61.55	2,930	48.75	18.45
Oderbrucker Barley	36.06	2,770	34.06	18.92
Wideawake—average of 4 check plots	57.114	2 710	64.25	55.74

SOYBEANS

The increasing importance of the soybean to Ohio agriculture, and in particular to the southern half of the state, has suggested the testing of rotations including this crop, as well as different varieties of soybeans in the regular variety tests. Nine varieties

were tested in 1913, with the results recorded in Table XIV, second column. Six of these varieties had been tested in 1912, and the average yield for the two seasons is recorded in column 3.

The New Era cowpeas were grown both years for seed. Their average yield is less than one-half that of soybeans.

For comparison, the 3-year average yields of these varieties, as grown at Wooster, are given.

TABLE XIV: Comparison of varieties of SOYBEANS.

Variety	Color of beans	Yield per acre Miami Co. 1913	Average yield per acre	
			2-year Miami Co.	3-year Wooster
		Bus.	Bus.	Bus.
Ohio 9100 (Ito San)	Yellow	12.81	19.74	21.79
Mongol	Yellow	15.29	27.64	27.58
Chestnut	Yellow	16.93	.....	27.79
Ohio 9035	Brown	16.67	19.83	28.51
Ebony	Black	15.62	21.89	24.42
Ohio 7496	Yellow	20.26	.....	29.25
Ohio 9016	Yellow	17.12	.....	30.64
New Era Cowpeas	Mottled	8.67	8.58	6.77
Medium Green (check) average of 4 plots	Green	15.81	17.90	25.83

SWINE HUSBANDRY

By THE DEPARTMENT OF ANIMAL HUSBANDRY

Pursuant to the plan outlined in Bulletin 241, an experiment has been begun in the raising of hogs on corn and forage crops to be harvested by what is known as the "hogging down" system. Nineteen acres of land has been set aside for this purpose, and divided by wire fences into a blue-grass pasture of 4 acres and 5 lots of three acres each to be cropped in a 5-year rotation as follows:

First year, corn; second year, corn; third year, rape and soy beans; fourth year, rye; fifth year, clover.

The green crops are to be supplemented with grain and tank age when necessary.

Seventy-five pigs were raised in the spring of 1913 and used in pasturing clover and hogging down rye and corn. Owing to the fact that the pigs came rather late in the spring and to a lack of facilities for doing experimental work, no very definite data were secured from the pasturing of the clover or the hogging down of the rye; however, some data were secured from hogging down corn. Two three-acre plots were hogged down with 60 pigs, all the pigs having access to only one plot at a time. The following is a summary of the results secured.

Results secured from hogging down 6 acres of corn with 60 pigs:

Initial weight, September 6, 1912		4564.5 lbs.
Final weight, October 18, 1913[1]		8264.5 lbs.
Total gain, 42 days[1]		3801.0 lbs.
Average daily gain per pig		1.51 lbs.
Feed consumed aside from standing corn	Shelled corn	335.0 lbs.
	Tankage	754.5 lbs.
Cost of feed consumed aside from standing corn[2]	Shelled corn $3.35; Tankage $18.86	$22.21

Return per acre:

Hogs @ 6c per pound	$34.31
Hogs @ 7c per pound	$40.64
Hogs @ 8c per pound	$46.98

The pigs used averaged 76 pounds in weight when they were turned on the corn and made an average gain of 1.51 pounds daily per pig during the 42 days required to hog down the 6 acres, and, with hogs at 6, 7 and 8 cents per pound live weight, showed a return of $34.31, $40.64 and $46.98 per acre respectively for the standing corn. It was estimated that the corn hogged down would yield about 45 to 50 bushels per acre. In addition to the standing corn, the pigs received three-tenths of a pound of tankage daily per pig, and some shelled corn when they were first turned on the standing corn and again at the close of the hogging down period when the corn on the plot was becoming very scarce. In regard to the net returns per acre as shown above it should be noted that, while charge is made for the tankage and shelled corn consumed by the pigs, yet all *profit* from the project is credited to the standing corn.

It was apparent from the season's work that a rotation furnishing a larger proportion of corn than the five-year rotation of corn, corn, rape and soybeans, rye, and clover, as started last year, would be better suited for this work, and the rotation has been changed to a four-year rotation of corn, corn, wheat or rye, and clover, and one of the five original three-acre plots is to be kept in continuous corn culture with rape and possibly rye seeded in the corn at the last cultivation, the corn to be hogged down each year. In view of the fact that rye soon becomes woody and tough, furnishing palatable green forage for a relatively short time, and that it is not especially well suited for hogging down as was done in 1913, a plan to allow the rye to mature and harvest it, or to use wheat instead of rye, is being considered.

The former four-acre bluegrass plot is being cut down to two acres of bluegrass, the other two acres being devoted to one acre each of alfalfa and rape.

[1]One pig taken out October 13, weight 101 pounds.
[2]Corn 56c per bushel. Tankage $50 per ton.

THE CLERMONT COUNTY EXPERIMENT FARM

SECOND ANNUAL REPORT, FOR 1913

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JUNE, 1914.

BULLETIN 275

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

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[1] With leave of absence. [2] In cooperation with Weather Service, U. S. Department of Agriculture.
[3] In cooperation with Bureau of Plant Industry, U. S. Department of Agriculture.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 276 — JUNE, 1914

REPORT OF THE FORESTER

EDMUND SECREST

At the close of the seventh fiscal year since the establishment by the legislature of a department of forestry at the Ohio Experiment Station, we are able to record with satisfaction a material advance in the forestry movement in Ohio. There has arisen a sentiment favorable to all lines of forestry work, the result in part, no doubt, of a nation-wide interest in the general conservation movement. Farmers are manifesting more and more interest in farm forestry. Institutions, both state and private, have come to realize that waste lands are better planted to trees than left idle and non-producing, and that their native forests are more productive when rightly managed. Municipalities are adopting forestry and forestry principles in the management of park properties. One large city has acquired land for the specific purpose of establishing a forest park. Colleges and universities have established courses of forestry in their curricula. A state law now requires forestry instruction as a branch of agriculture in the public schools. Everywhere there is being created a helpful sentiment in favor of this conservation movement.

During the past fiscal year, as heretofore, five lines of work have been continued, with the addition of several new phases.

Forest nurseries are established at five locations, the principal one being on the Experiment Station farm at Wooster. It is the policy of the Station to have on hand a variety of forestry stock to be used in the various phases of the experimental planting which is being carried on throughout the state. No great quantities of stock are grown, except of a few well tried species which have become popular with planters, though stock of other species is maintained for research work. No particular effort has been made to keep on

Mean temperature, January, 1913

Figure 1. Average temperature for January, 1913. The mean temperature for the state was 36.0°. The highest local monthly mean was 43.2° in Lawrence county, and 43.0° in Meigs county; the lowest local monthly mean was 29.9° in Fulton county. The highest temperature reported was 70° in Meigs county on the 20th and 31st, and lowest was 3° in Wood county on the 9th. The month was marked by frequent and unusually warm days, being the warmest January on record since 1890 when the mean temperature was 38.8°.

Temperature departures, January, 1913

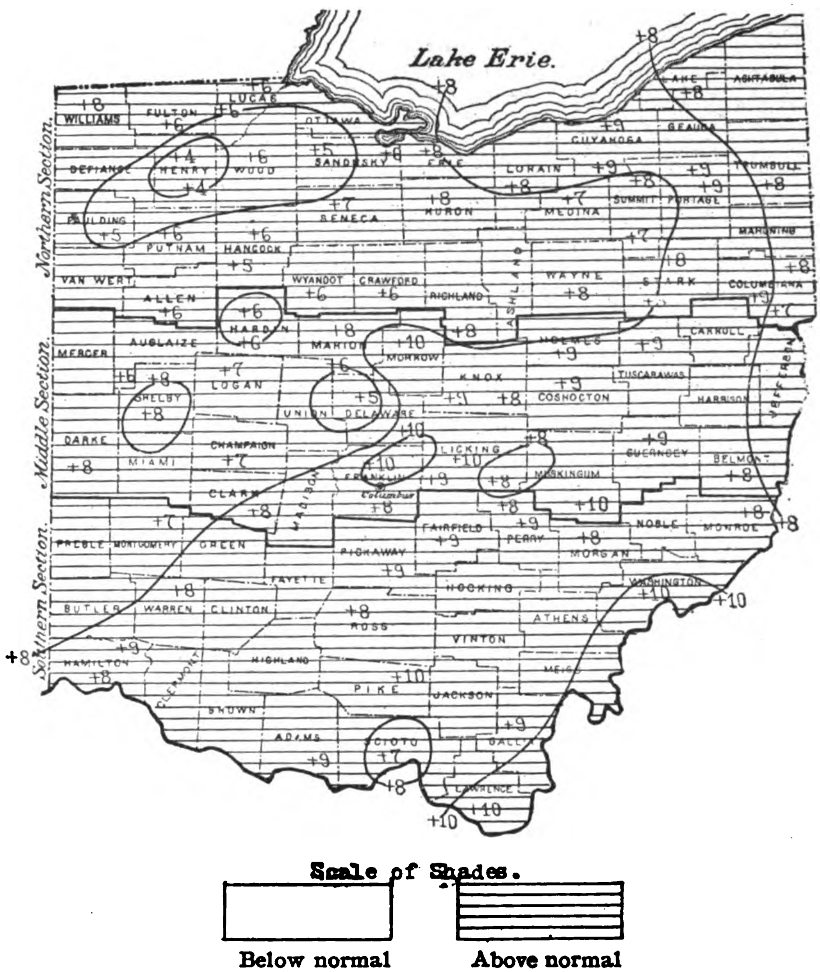


Figure 2. Temperature departures from the normal for January, 1913. The temperatures were far above normal throughout the whole state, ranging from 3.9° above the normal in Henry county, to 11.1° in Washington county, 10.2° in Lawrence county, and 10.3° in Franklin county. The state as a whole averaged 7.8° above the normal.

Precipitation, January, 1913

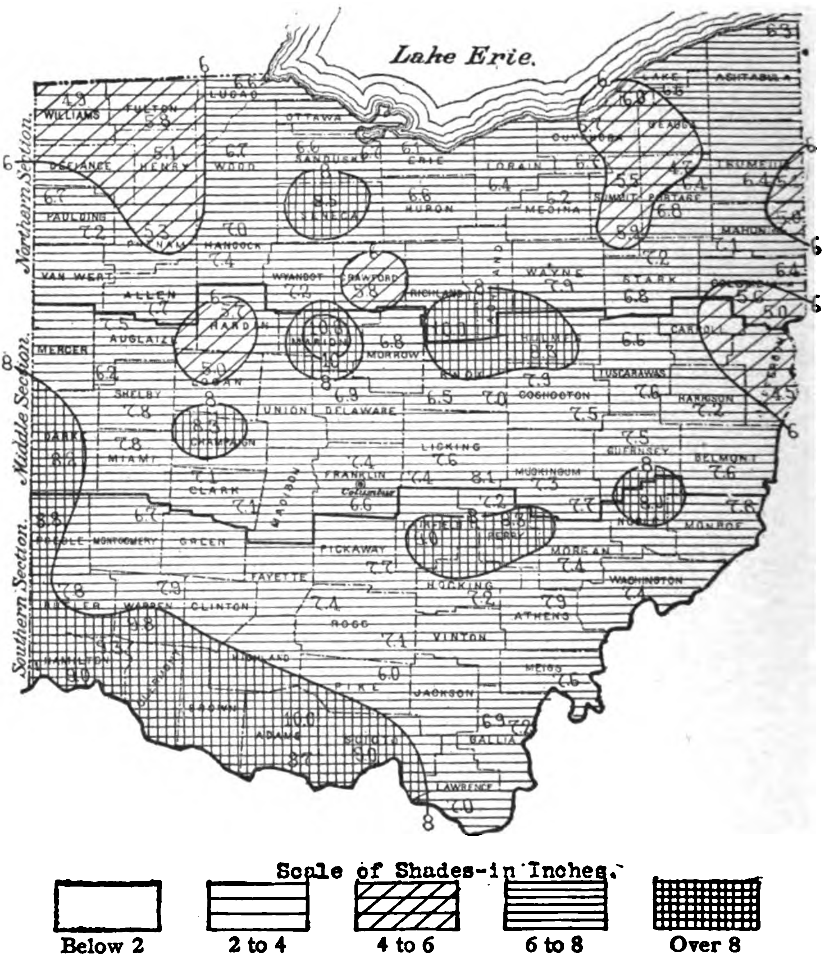


Figure 3. Precipitation during January, 1913. The average precipitation for the state was 7.01 inches, making the month by far the wettest January on record. Not only was the January record broken, but the state averages for any other month have been larger only five times in the last fifty years. The largest amount reported was 10.80 inches in Marion county, and least was 4.50 inches in Jefferson county. The precipitation was heaviest in the southeastern counties and in scattered sections of the central part of the state. The northeastern and northwestern counties showed the lightest falls. The heavy rainfall caused high water in all streams and rivers during the first part of the month.

Precipitation departures, January, 1913

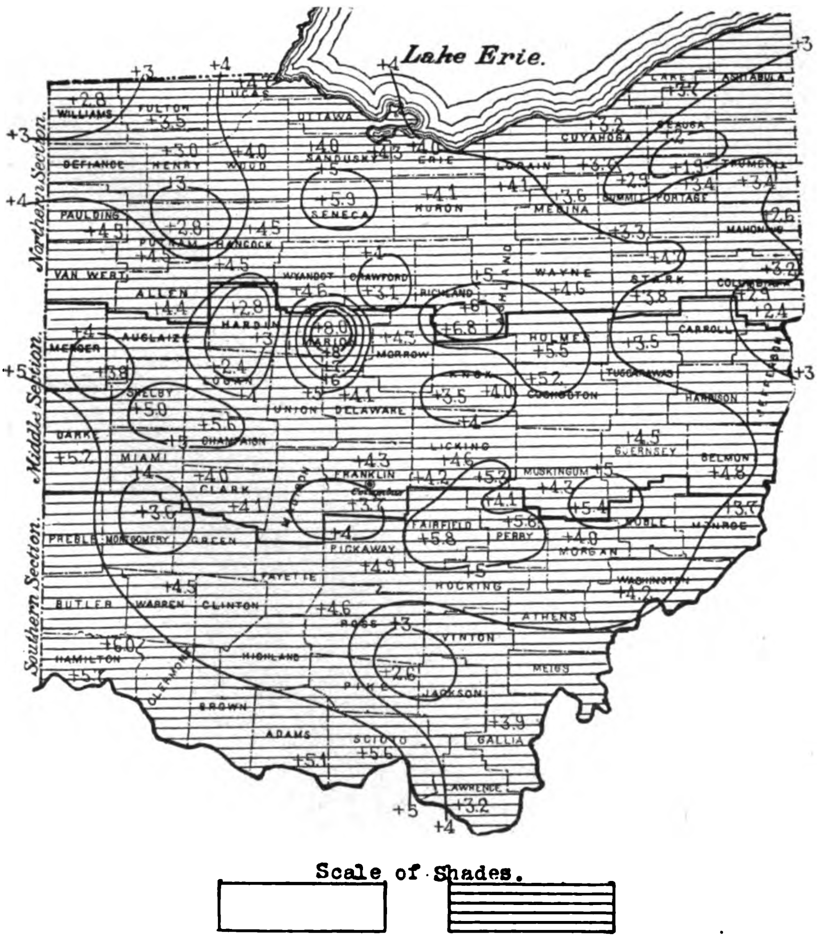


Figure 4. Departures from the normal precipitation for January, 1913. The average departure from the normal precipitation for the state was 4.17 inches, ranging from 1.90 inch in Portage county to 8.01 inches in Marion county. The number of rainy days averaged between 15 and 20 for nearly every station in the state, so that the mild temperatures were of little value for the carrying on of outdoor work.

Snowfall, January, 1913

Below 5	5 to 10	10 to 15	15 to 20	Over 20

Figure 5. Snowfall for January, 1913. The average snowfall for the state was 8.6 inches. It was below the normal in nearly all except the northern counties, nearly all the precipitation falling as rain in the southern and border counties. What snow did fall remained on the ground but a short time, although in some of the northern counties the ground was covered from the third to the fifth, and on the twenty-eighth and twenty-ninth. The greatest amount for the month was 24.0 inches in Crawford county.

Mean temperature, February, 1913

Figure 6. Average temperatures for February, 1913. The mean temperature for the state was 26.7°. The highest local monthly mean was 35.0° degrees in Lawrence county and the lowest local monthly mean was 22.4° in Fulton county. The highest temperature reported was 77°, in Belmont county on the 21st, and the lowest was 15° below zero in Perry county on the 6th. Low temperatures prevailed during the first half of the month, but during the last half the weather was considerably milder, especially from the 19th to the 22nd.

Temperature departures, February, 1913

Figure 7. Temperature departures from the normal for February, 1913. The temperatures averaged 0.5° below normal for the state as a whole, ranging from 3.8° below normal in Franklin county to 2.1° above normal in Highland county. The month showed a sharp contrast to January, being nearly 10° colder.

Precipitation, February, 1913

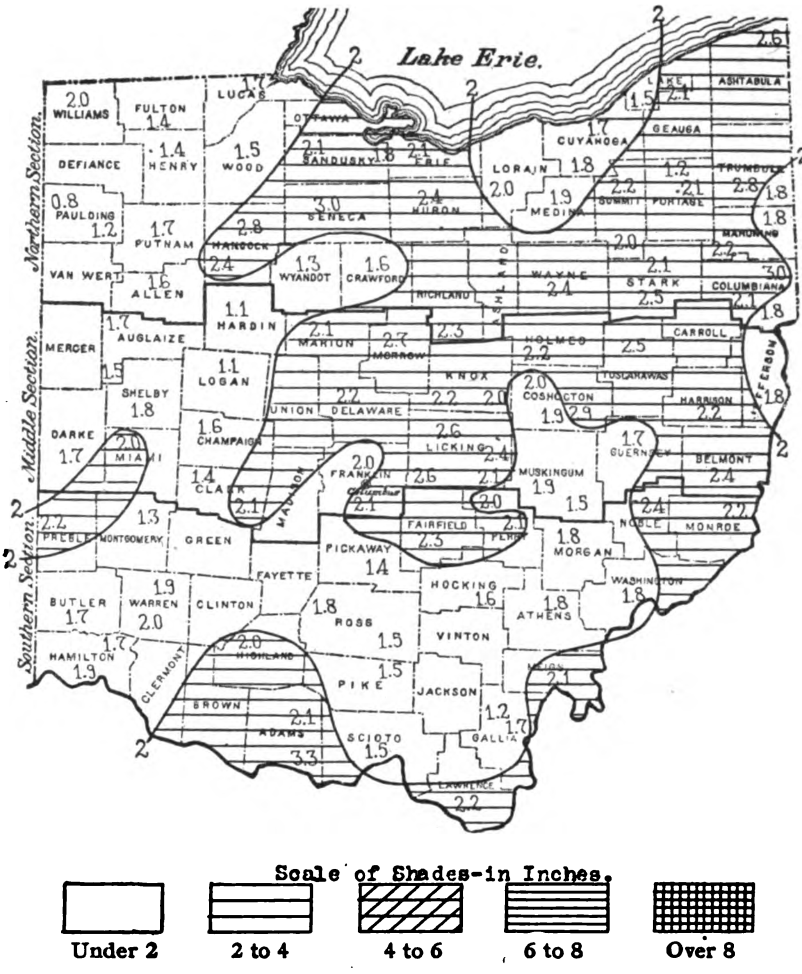


Figure 8. Precipitation during February, 1913. The average precipitation for the state was 1.94 inch, ranging from 3.32 inches in Adams county to 0.75 inch in Paulding county. With the exception of the 3rd the precipitation was scattered and quite light until near the close of the month.

Precipitation departures, February, 1913

Figure 9. Departures from the normal precipitation for February, 1913. The average departure from the normal precipitation for the state was 0.77 inch below normal, ranging from 2.15 inches below normal in Pike county to 0.36 inch above normal in Columbiana county. Precipitation was in the form of snow during practically all of the first three weeks and was mostly in the form of rain during the last week. The number of rainy days averaged 8.

Snowfall, February, 1913

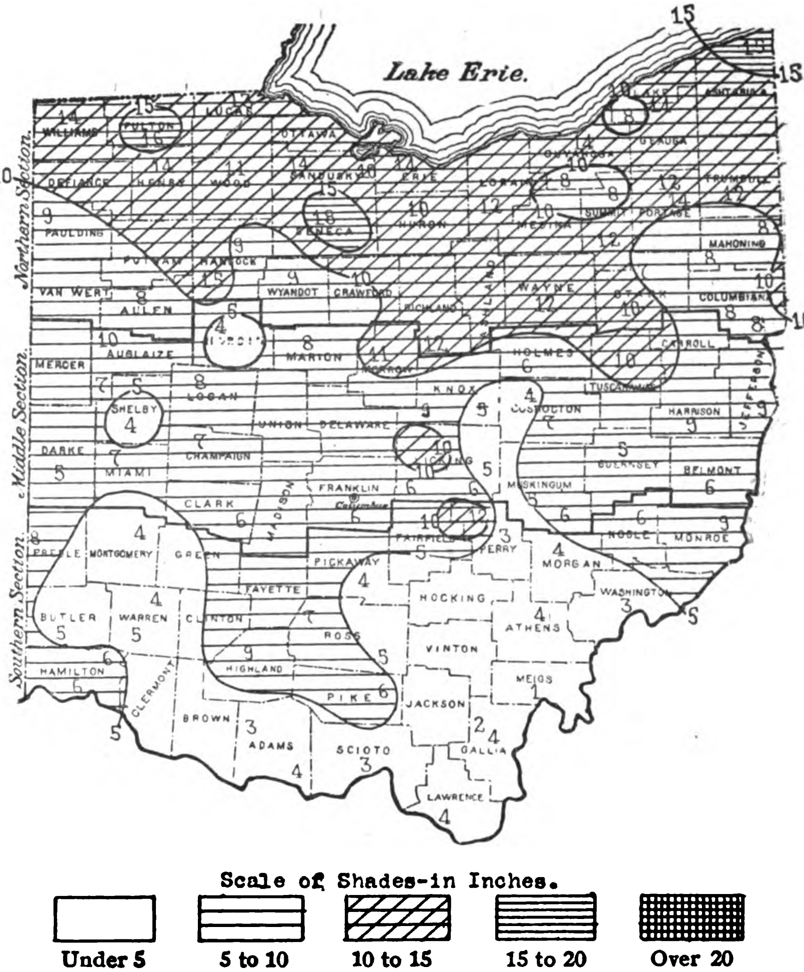


Figure 10. Snowfall for February, 1913. The average snowfall for the state was 6.9 inches, ranging from 18 inches in Seneca county to 1 inch in Meigs county. The snowfall averaged above normal in nearly all the northern counties and in scattered counties throughout the south. The snow of the 2nd and 3rd was exceptionally dry. The ground was generally well protected by snow from the 3rd to the 10th of the month when the coldest weather was experienced.

Mean temperature, March, 1913

Figure 11. Average temperatures for March, 1913. The mean temperature for the state was 40.1°. The highest local monthly mean was 47.6° in Gallia and in Lawrence counties; the lowest local monthly mean was 34.7° in Fulton county. The highest temperature reported was 80° in Adams county on the 14th and the lowest 8° below zero in Portage county on the 8th. Unusually warm weather for the time of year was experienced on the 14th and 20th. The 7th was the coldest day at most stations, although cold spells occurred on the 16-17th, 22nd, and 27-29th.

Temperature departures, March, 1913

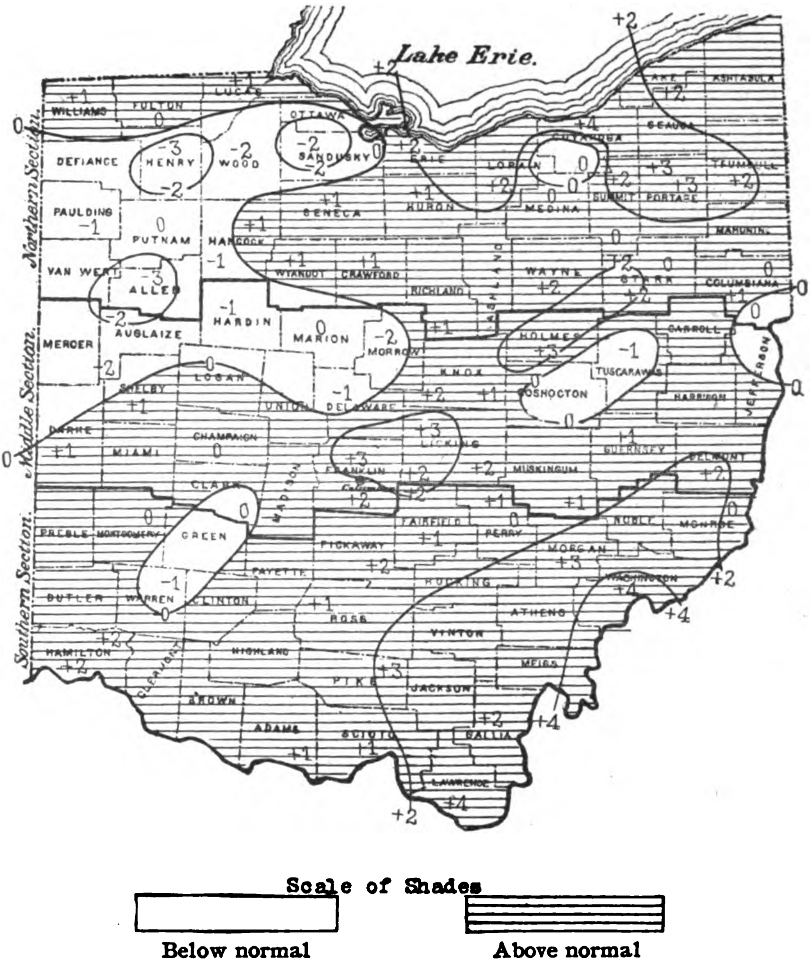


Figure 12. Temperature departures from the normal for March, 1913. The state as a whole averaged 0.9° above the normal, ranging from 3.2° below the normal in Henry county to 3.8° above the normal in Cuyahoga county and 4.1° above the normal in Washington county.

Precipitation, March, 1913

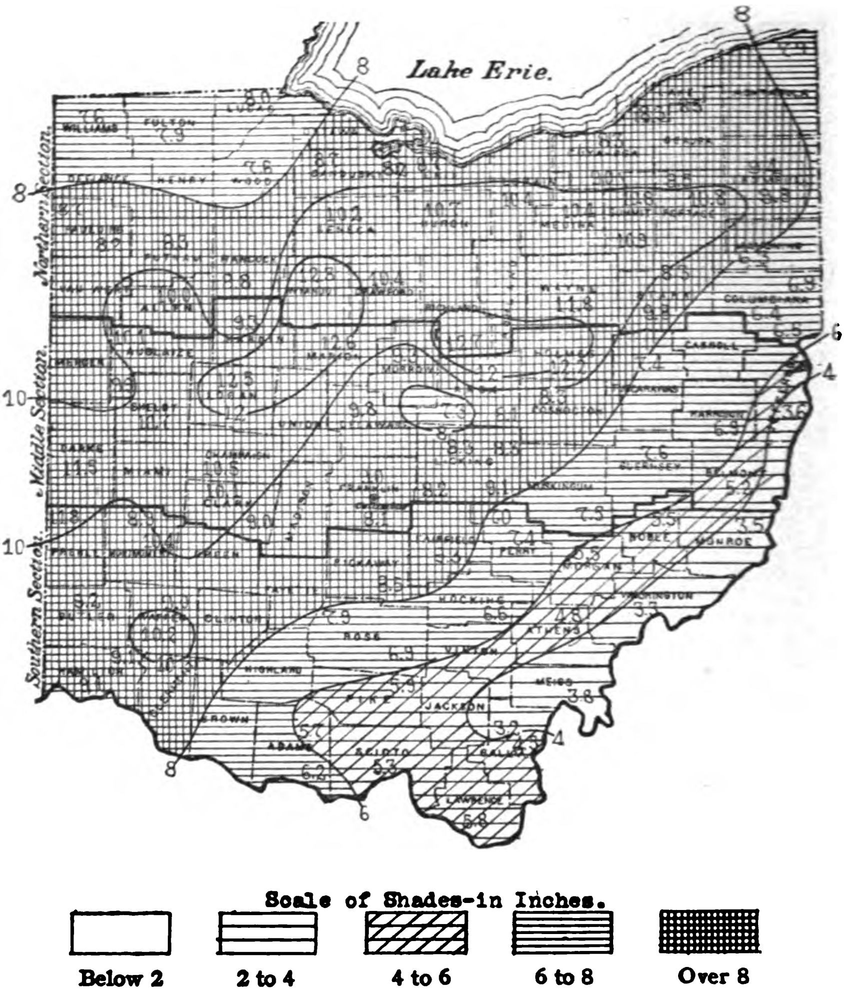


Figure 13. Precipitation for March, 1913. The average precipitation for the state was 8.40 inches, making the month the wettest March on record. The state averages for the other months have been greater in but two instances in the last fifty years. The largest amount reported was 12.68 inches in Richland county, and the least was 3.18 inches in Gallia county. The area of heaviest precipitation extended across the state from southwest to the northeast and followed closely the boundary line between the Lake Erie and Ohio River watersheds.

During the first three weeks the precipitation was rather light but from the 23rd to 27th rain fell almost continuously, and during much of the time at an excessive rate. At several stations in the middle-northern counties over ten inches fell in these five days, and over twelve inches during the month.

Precipitation departures, March, 1913

Scale of Shades.

Below normal | Above normal

Figure 14. Departures from the normal precipitation for March, 1913. The average departure from the normal precipitation for the state was 5.28 inches above the normal, ranging from 1.15 inch below normal in Monroe county to 9.01 inches above normal in Logan county, 9.07 inches above normal in Wyandot county, and 9.19 inches above normal in Marion county. The average number of rainy days was 13.

The heavy rains of the 23rd-27th caused the most destructive flood in the history of the state. The estimated property loss in Ohio due to this flood was $113,660,000, and there were 467 lives lost. The damage to agricultural interests was very great.

Snowfall, March, 1913

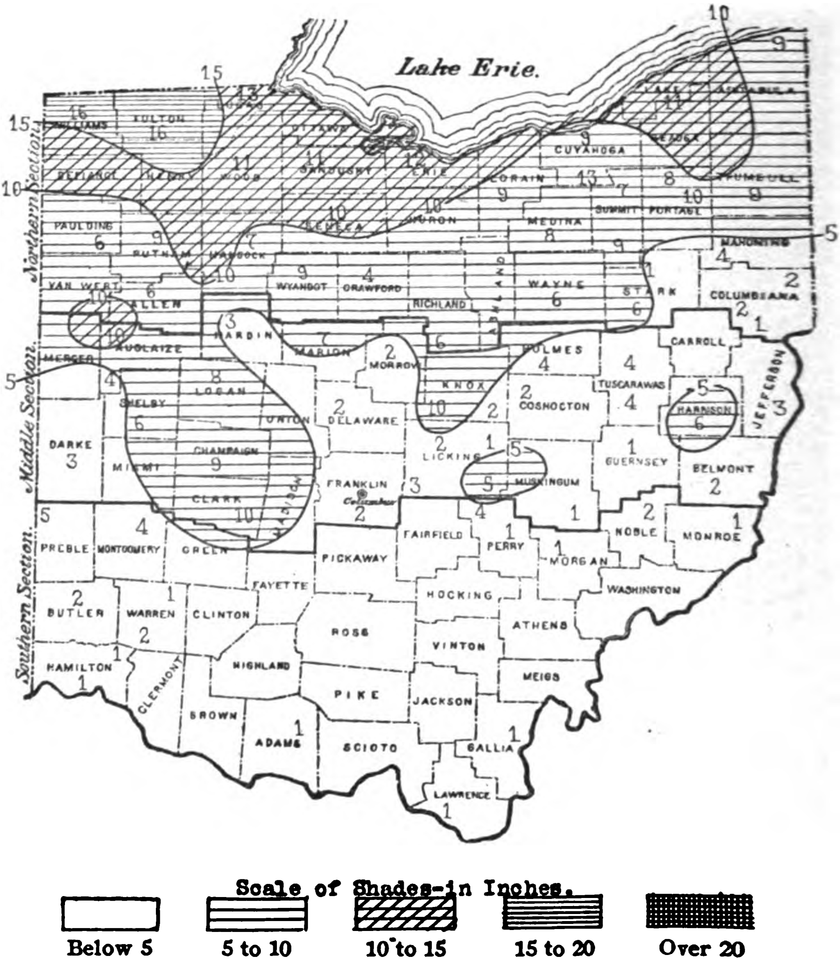


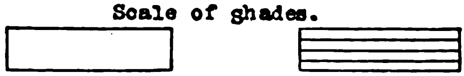
Figure 15. Snowfall for March, 1913. The average snowfall for the state was 5.1 inches, ranging from 16.3 inches in Williams county and 15.5 inches in Fulton county to a trace in some of the southern counties. It averaged above normal in nearly all of the northern counties, but was considerably below normal in the southern counties.

Mean temperature, April, 1913

Figure 16. Average temperatures for April, 1913. The mean temperature for the state was 50.0°. The highest local monthly mean was 55.0° in Lawrence county, and the lowest local monthly mean was 46.1° in Lake county. The highest temperature reported was 90° in Columbiana and Meigs counties, and the lowest was 18° in Portage county. Cloudy and cool weather prevailed during the first two weeks, and the 20th and 21st were unseasonably cool. The last few days were also cool but the rest of the month was bright and pleasant.

Temperature departures, April, 1913

Scale of shades.



Below normal — Above normal

Figure 17. Temperature departures from the normal for April, 1913. The state as a whole averaged 0.6° above the normal, ranging from 2.7° below normal in Hardin county to 2.6° above normal in Holmes county, and 3.4° above the normal in Summit county.

Precipitation, April, 1913

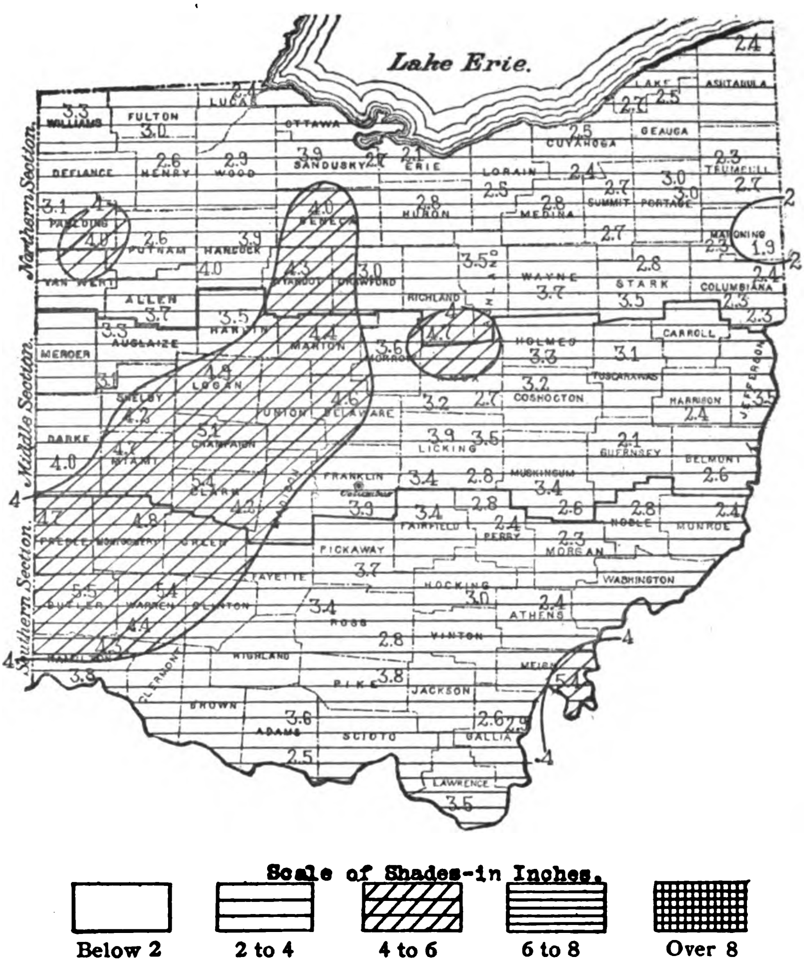


Figure 18. Precipitation for April, 1913. The average precipitation for the state was 3.35 inches. The largest amount was 5.50 inches in Butler county, although 5.36 inches was reported in Clark county. The least was 1.87 inch in Mahoning county. The greater part of the rainfall occurred during the first half of the month, although on the 26-28th quite general rains prevailed. The area of heaviest precipitation extended from the southwestern corner of the state to a point slightly south of the western end of Lake Erie. Practically no snow fell during the month.

Precipitation departures, April, 1913

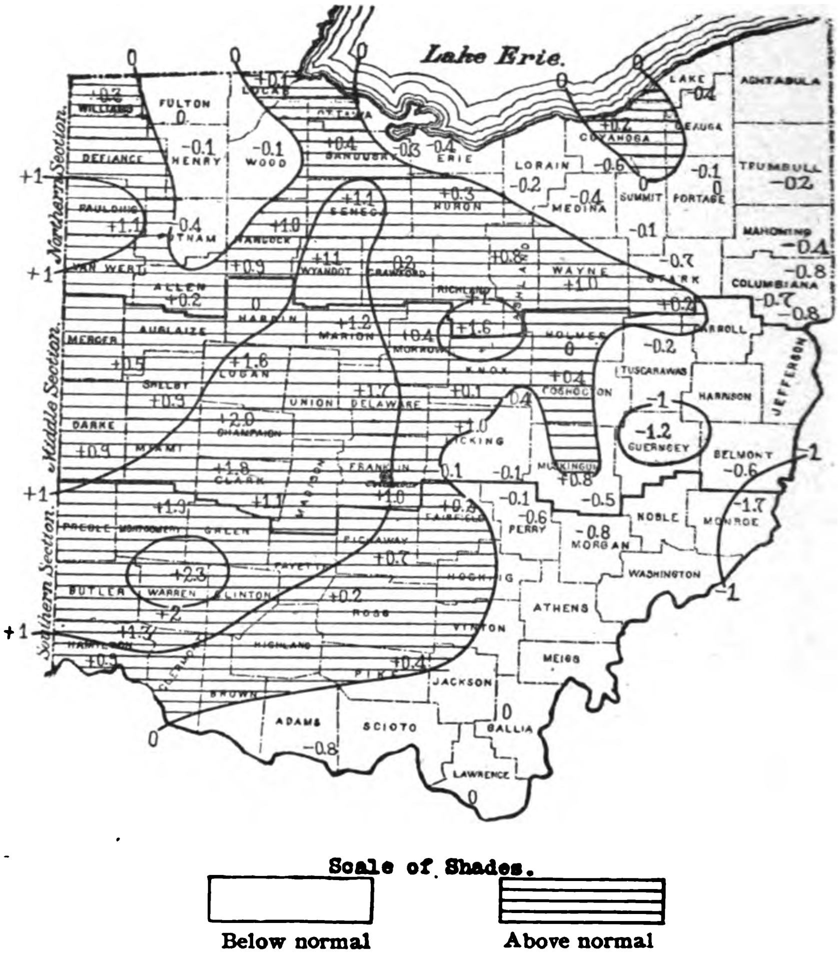


Figure 19. Departures from the normal precipitation for April, 1913. The average departure from the normal precipitation was 0.30 inch above the normal, ranging from 1.69 inch below normal in Monroe county to 2.33 inches above normal in Warren county. The number of rainy days averaged 10; no excessive precipitation was reported.

Mean temperature, May, 1913

Figure 20. Average temperature for May, 1913. The mean temperature for the state as a whole was 60.3°, ranging from 55.8° in Lake county, and 56.0° in Ashtabula county, to 65.8° in Hamilton county. The highest temperature reported was 95° in Meigs county on the 4th, and the lowest was 23° in Columbiana county on the 11th and 12th, and in Coshocton county on the 11th.

At nearly all stations the warmest weather of the month was experienced during the first five days, a week of cooler weather followed with record breaking minimum temperatures on the 11th at six stations, while the previous lowest May record was equalled at ten others on the same date. More seasonable temperatures prevailed from the 12th to the 18th, but there were only two or three days from the 19th to the close of the month with the temperature above normal.

Temperature departures, May, 1913

Figure 21. Temperature departures for May, 1913. The temperature for the state as a whole was 0.6° below normal, ranging from 2.6° below normal in Logan county to 2.2° above normal in Darke county. A narrow strip along the western edge of the state, portions of a few of the southeastern counties along the Ohio River, and a few of the north-central counties were above normal but all the rest were below normal.

Precipitation, May, 1913

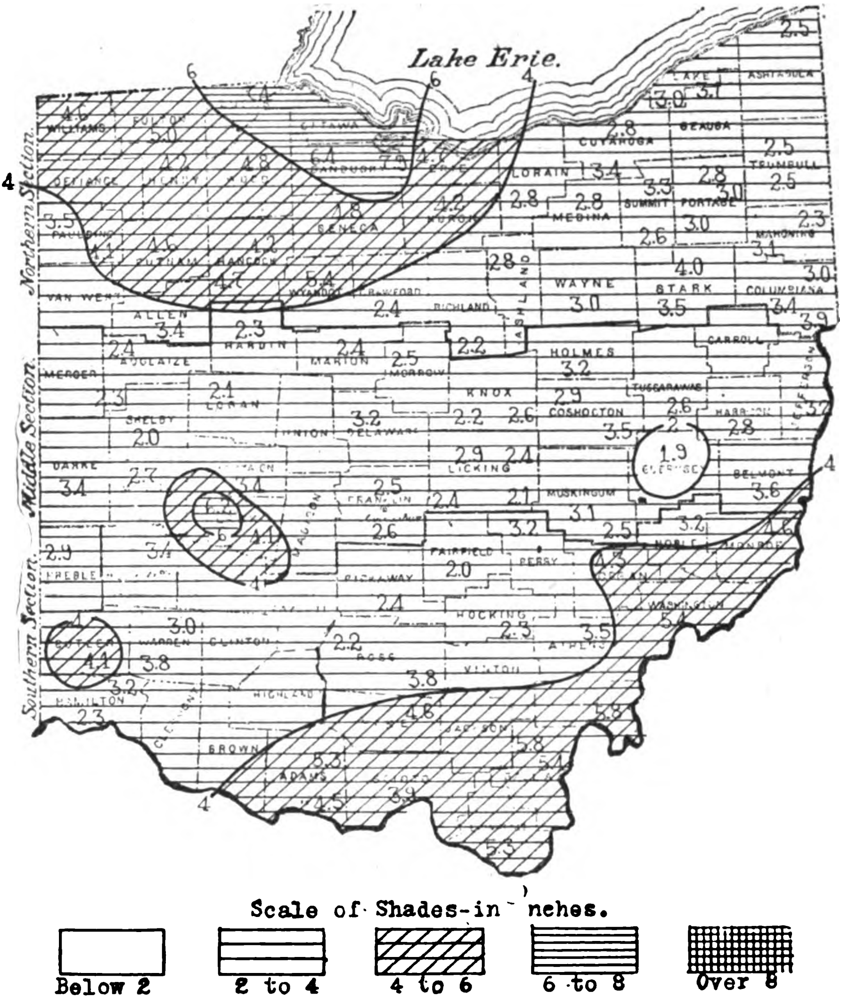


Figure 22. Precipitation for May, 1913. The average precipitation for the state as a whole was 3.53 inches., ranging from 7.94 inches in Sandusky county to 1.86 inch in Guernsey county. The first part of the month was comparatively dry, but during the remainder of the month showers were frequent, and in the northwestern and southeastern, as well as in Clark and in Butler counties, were heavy. At Toledo, in Lucas county, 3.57 inches fell in 24 hours, on the 26th and 27th. The rainfall in the latter part of the month hindered farm work greatly, especially delaying corn planting.

Precipitation departures, May, 1913

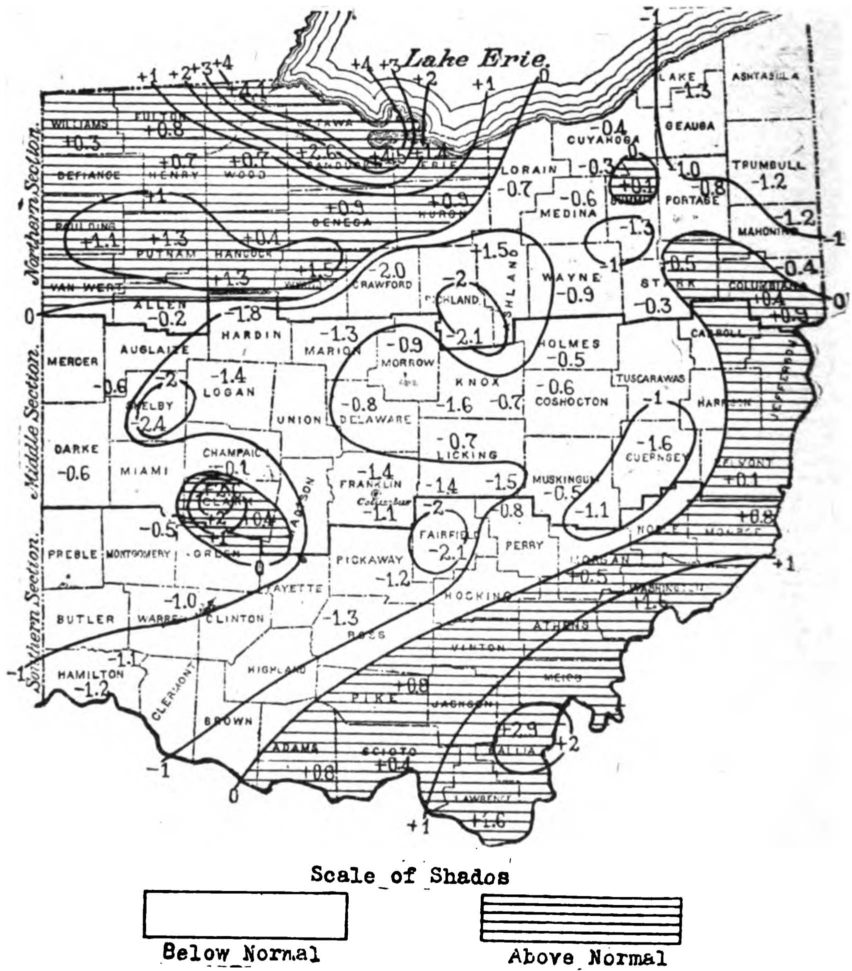


Figure 23. Precipitation departures for May, 1913. The precipitation for the state as a whole averaged 0.12 inch below the normal, ranging from 4.49 inches above normal in Sandusky county to 2.35 inches below normal in Shelby county. The average number of rainy days was 10.

Mean temperature, June, 1913

Figure 24. Average temperature for June, 1913. The mean temperature for the state was 69.8°. The highest local monthly mean was 74.8° in Hamilton county; the lowest local monthly mean was 65.0° in Portage county. The highest temperature reported was 105° in Columbiana county on the 30th, and the lowest was 29° in Portage county on the 10th.

The first half of the month was generally cool, and the last half generally warm. Record breaking minimum temperatures for the month of June were experienced at 4 stations, and 6 others equalled their previous June record. The maximum temperature records for June were broken at 12 stations and were equalled at 11 others. During the latter part of the month an unusually large number of heat prostrations occurred.

Temperature departures, June, 1913

Figure 25. Temperature departures from the normal for June, 1913. The temperature was above normal for most stations throughout the state, ranging from 3.2° above normal in Columbiana county to 1.1° below normal, also in Columbiana county. The state as a whole was 0.6° above normal.

Precipitation, June, 1913

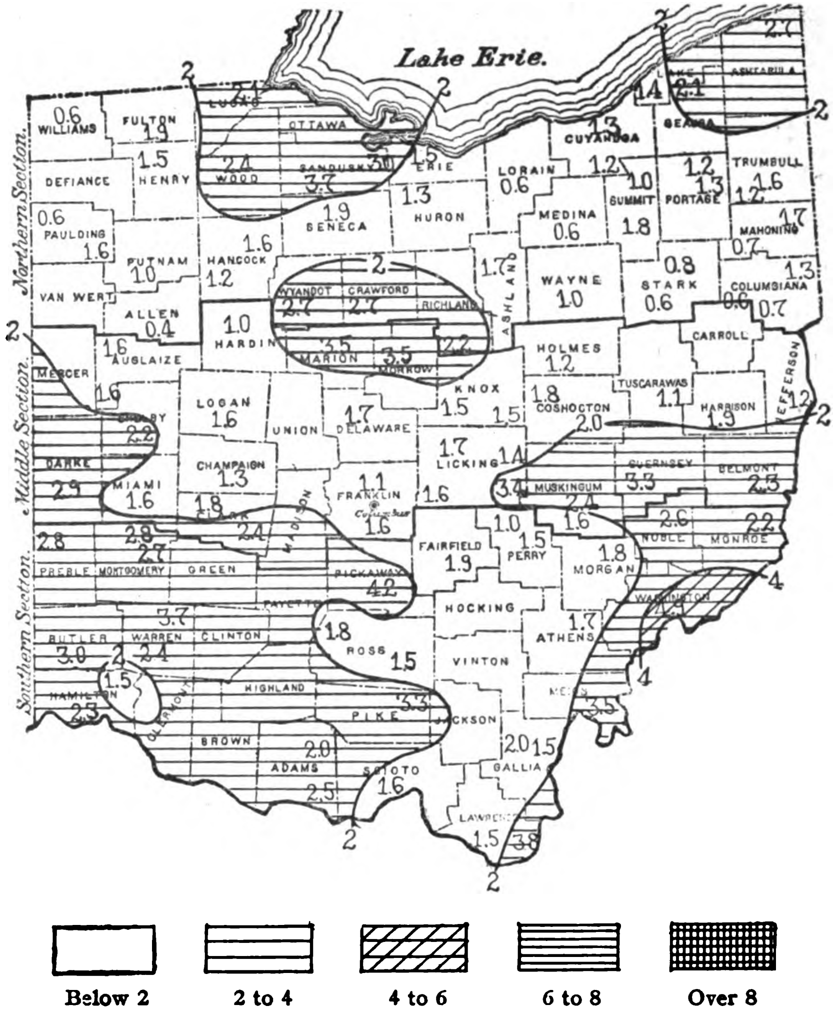


Figure 26. Precipitation during June, 1913. The average precipitation for the state as a whole was 1.87 inch, making this one of the driest Junes on record. Several stations reported less than one inch for the whole month, Lima being least with only 0.36 inch. Marietta had the heaviest precipitation, 4.94 inches. In nearly all instances the rainfall occurred with thunderstorms, and in many places these storms were severe, considerable damage being done by wind, lightning and hail.

Precipitation departures, June, 1913

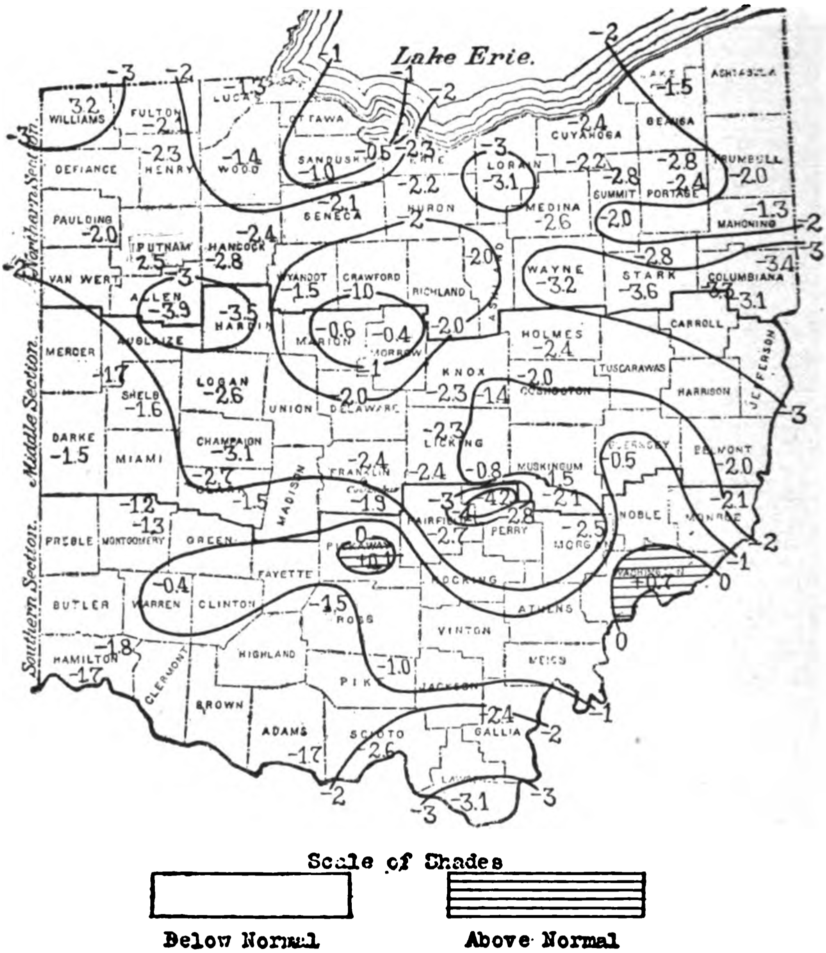


Figure 27. Departures from the normal precipitation for June, 1913. The precipitation for June was 2.04 inches below normal, ranging from 4.18 inches below normal in Perry county to 0.71 inch above normal in Washington county. The precipitation was above normal at only two stations in the whole state. The number of rainy days averaged 6.

Mean temperatures, July, 1913

Figure 28. Average temperature for July, 1913. The mean temperature for the state was 74.5°. The highest local monthly mean was 103° reported in Clark county on the 29th, and in Hamilton and Montgomery counties on the 30th; the lowest local monthly mean was 40° in Portage county on the 11th.

This was one of the warmest Julys on record in this state, the state average having been higher but five times in the past thirty-one years. The month began and ended with excessively high temperatures, but from the 6th to the 26th the temperatures were generally close to normal. Many prostrations and deaths resulted during the two hot periods.

Temperature departures, July, 1913

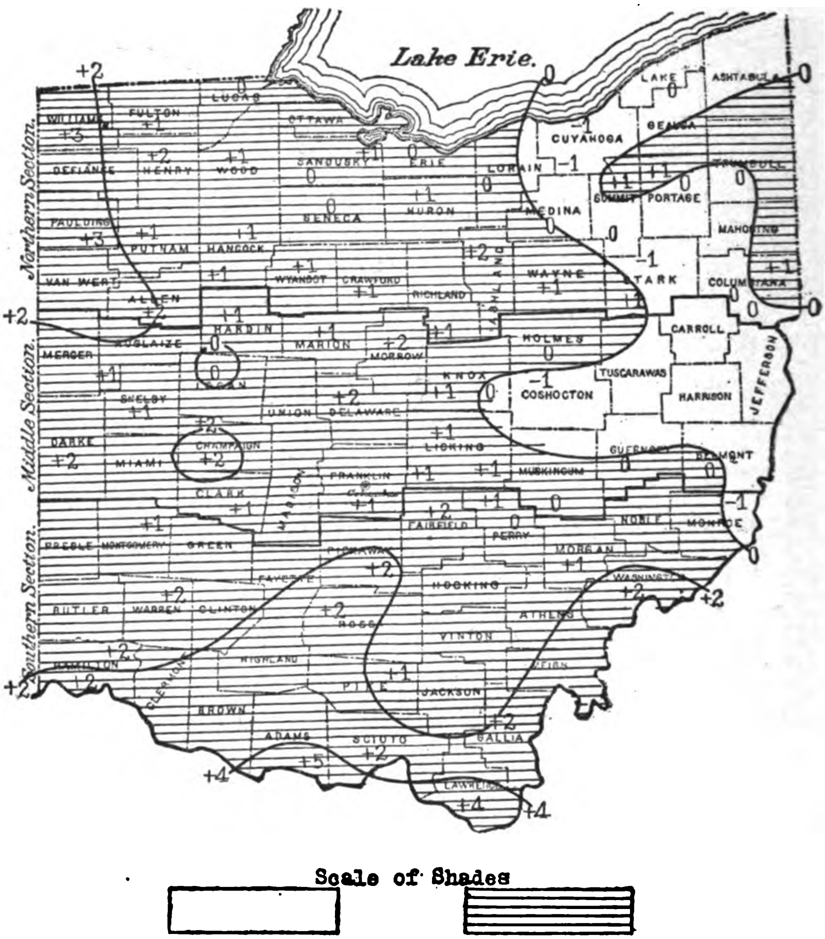


Figure 29. Temperature departures from the normal for July, 1913. The temperature was above normal at most stations throughout the st ate, rangng from 3.4° above normal in Paulding county to 0.8° below normal in Stark iand Coshocton counties. The state as a whole averaged 1.0° above normal.

The average number of clear days was 16, against an average of 12 partly cloudy, and 3 cloudy days. The percentage of sunshine was also above normal.

Precipitation, July, 1913

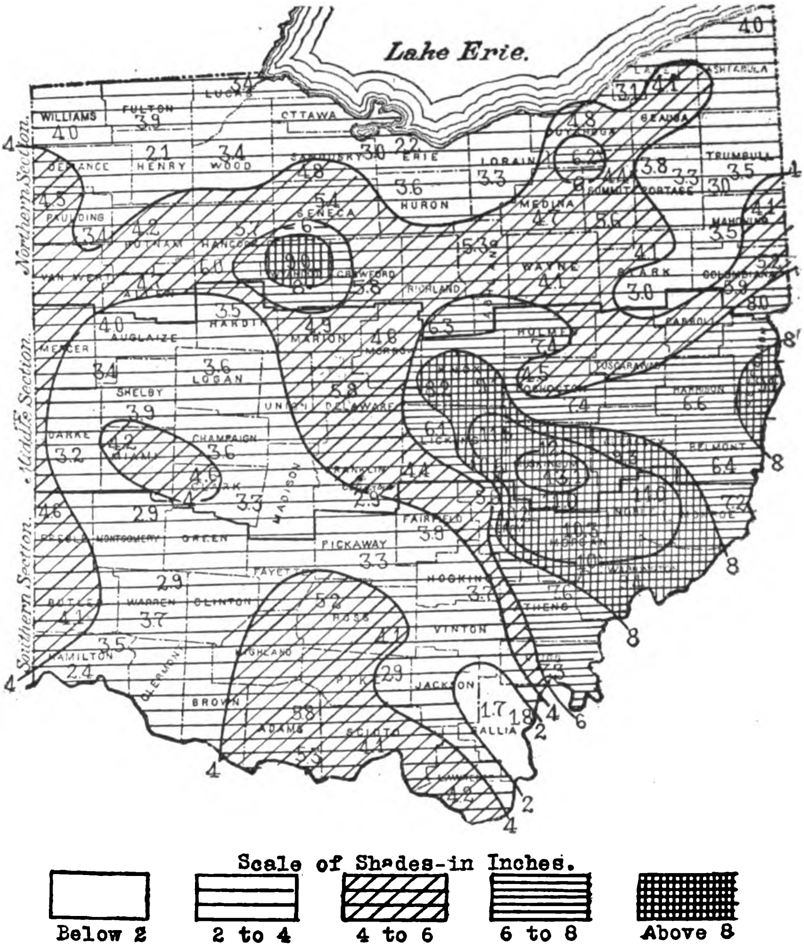


Figure 30. Precipitation during July, 1913. The average precipitation for the state as a whole was 5.20 inches, making this one of the wettest Julys on record. Only three times in the past thirty-one years has this precipitation average been greater. Thurman, in Gallia county, had the smallest monthly rainfall, reporting only 1.71 inch. Zanesville, in Muskingum county, reported 13.12 inches, considerably over half of which fell on the 14th and 15th of the month. On the night of the 13th and morning of the 14th an almost unprecedented rainfall for this state occurred over the Muskingum watershed, causing the lower Muskingum river to rise about 5 feet above flood stage. Also all the smaller streams overflowed their banks, some of them going higher than ever before. Heavy damage was done to crops, railroads, highways and bridges.

Heavy rainfalls also occurred over the Sandusky river valley on the same date, and caused considerable damage. Several severe thunderstorms were reported in the state during the month, heavy loss resulting.

Precipitation departures, July, 1913

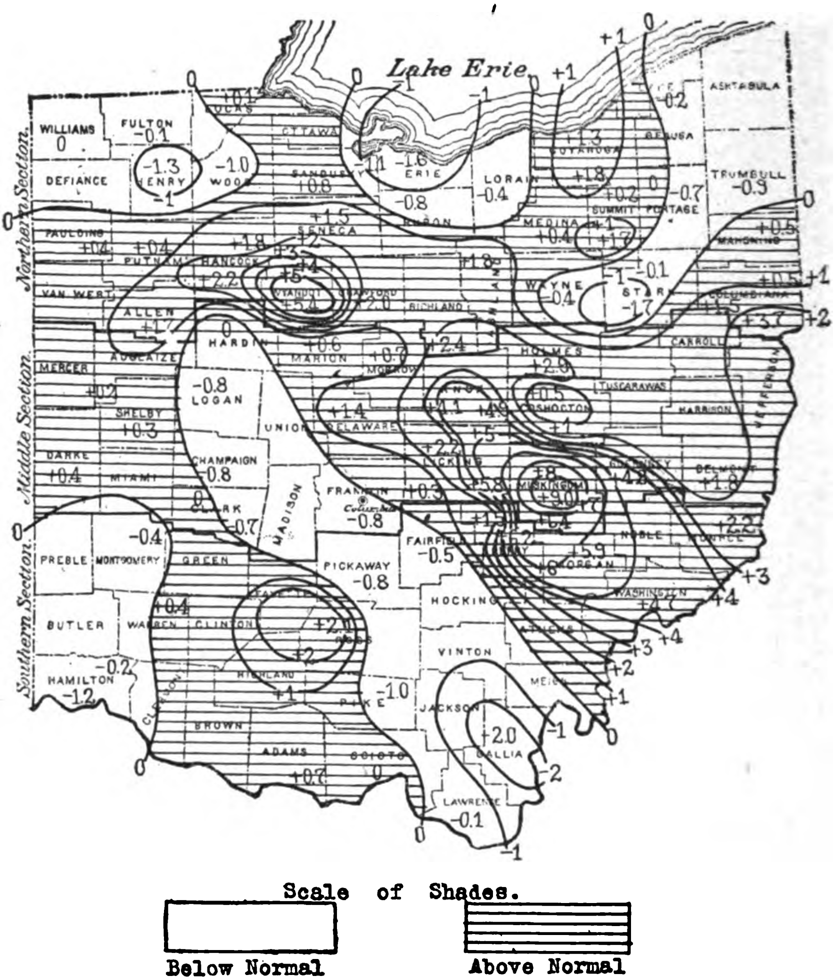


Figure 31. Departure from the normal precipitation for July, 1913. The precipitation for July averaged 1.11 inch above normal for the state as a whole, ranging from 8.97 inches above normal in Muskingum county to 2.03 inches below normal in Gallia county. The rainfall was mostly local, being excessive in a great many instances. The number of rainy days averaged 11.

Mean temperature, August, 1913

Figure 32. Average temperature. The average temperature for the state as a whole was 73.3°. The highest temperature reported during the month was 102° at Clarington, Monroe county, on the 9th, and the lowest was 39° at Garrettsville, Portage county, and New Waterford, Columbiana county, on the 25th.

Warm weather prevailed during the most of the period from the 7th to the 20th, inclusive, and on the 28th. On the 9th, 16th, 17th, 18th and 28th the afternoon temperatures reached close to the 100° mark in nearly all counties away from the influence of Lake Erie. Rather cool weather was experienced on the 4th, 5th, 24th, 25th, 30th and 31st.

Temperature departures, August, 1913

Figure 33. Temperature departures. The mean temperatures for the stations in the state averaged 2.0° above the normal. The greatest excess in temperature occurred in southern and western counties and the least in the eastern counties.

Precipitation, August, 1913

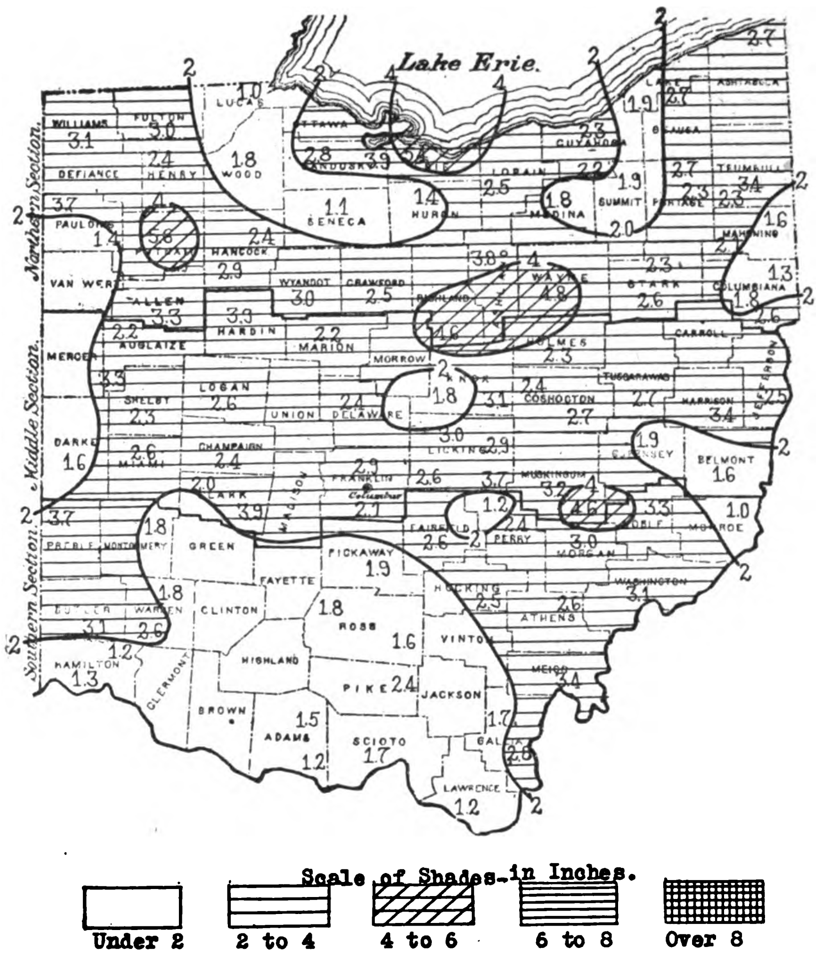


Figure 34. Precipitation for August, 1913. The average precipitation for the state as a whole was 2.52 inches. In general the greatest amount of rainfall occurred in the Muskingum and middle Maumee watersheds, and the least amount in several areas around the border of the state. The greatest amount recorded at one station was 5.57 inches at Ottawa, Putnam county, where there was a fall of 3.47 inches within 24 hours on the 21st and 22nd, and the least was 0.96 inch at Toledo. With the exception of the 21st and 22nd, the rains were generally scattered and light.

Precipitation departures, August, 1913

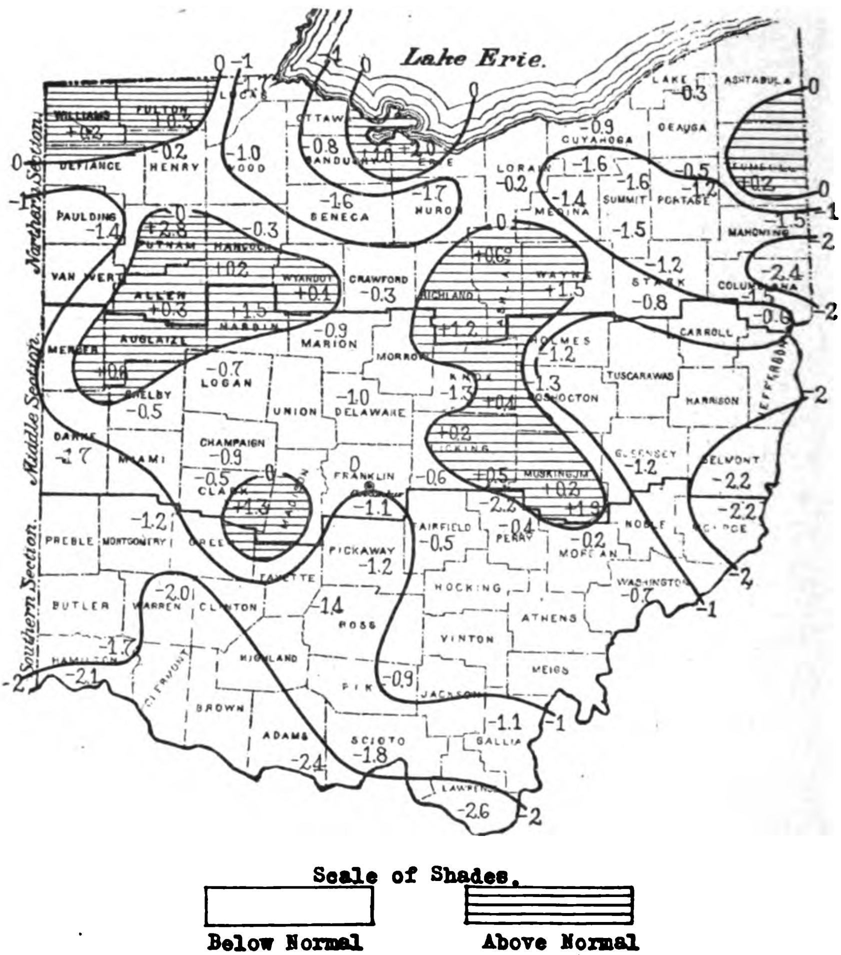


Figure 35. Precipitation departures for August, 1913. The precipitation averaged 0.64 inch below the normal amount for that month. More than the normal amount fell in a number of northern and middle counties, but in the southern counties there was a general deficiency. There was an average of only 6 rainy days during the month.

Mean temperature, September, 1913

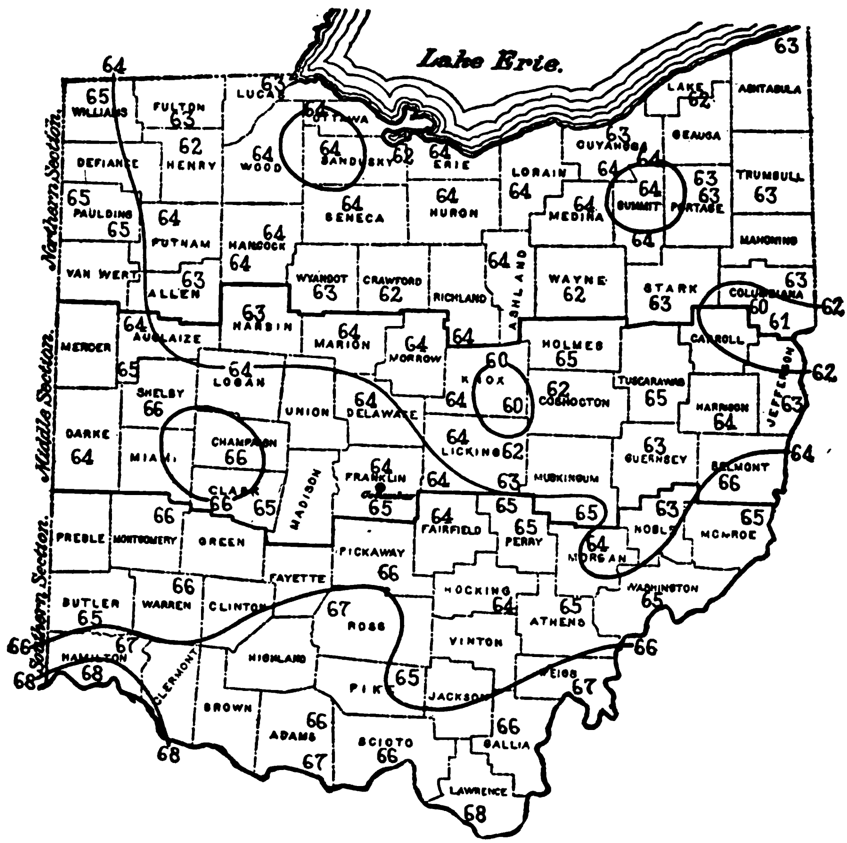


Figure 36. Average temperature for September, 1913. The average temperature for the state as a whole was 64.1°. The highest temperature reported during the month was 102° at Hamilton on the 2nd, and the lowest was 26° at Green Hill and Toboso on the 23rd.

The month was characterized by unusual temperature extremes. The first 7 days were exceptionally hot and the 23rd was exceptionally cold. All previous high temperature records for September were broken during the first 3 days at 9 stations and equalled at 9 others, and the low temperature records for September were broken at 6 stations and equalled at 11 others, on the 23rd. From the 9th to the 28th, inclusive, the temperatures were generally below normal. Frost and freezing temperatures were general, except along the lake shore and the Ohio river on the 23rd. Frost occurred also quite generally on the 14th, and in scattered localities on the 10th, 11th, 27th and 28th.

Temperature departures, September, 1913

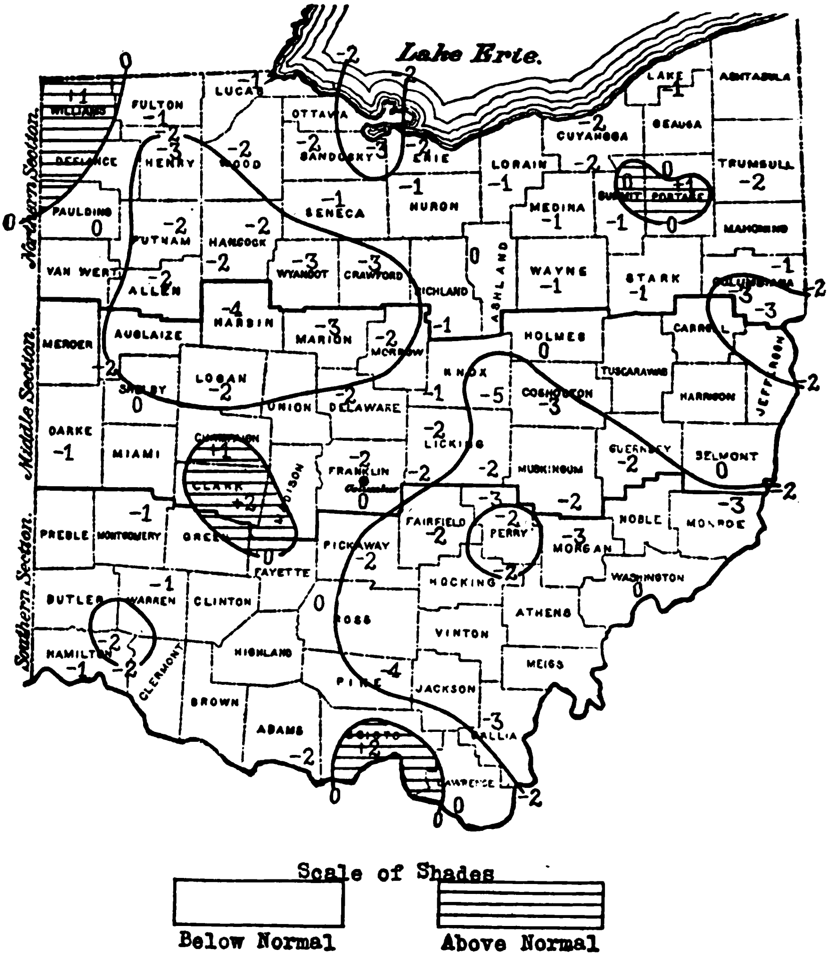


Figure 37. Temperature departures for September, 1913. The mean temperature for the stations in the state averaged 1.5° below the normal. It was below normal at practically all stations.

Precipitation, September, 1913

Figure 38. Rainfall for September, 1913. The average amount of rainfall for the state was 2.37 inches. The greatest amount fell in Stark and Tuscarawas counties and the least in Ashtabula county.

There was but little rainfall during the hot weather of the first week and the droughty conditions became quite serious in some localities. Light rains fell on the 7th, 8th and 12th, and during the 3rd week there was rain almost every day, and the drought was broken in all parts of the state. The last week was generally fair and cool, except on the 29th and 30th when light rains fell. Traces of snow were reported on the 22nd in Ashland, Auglaize and Knox counties.

Precipitation departures, September, 1913

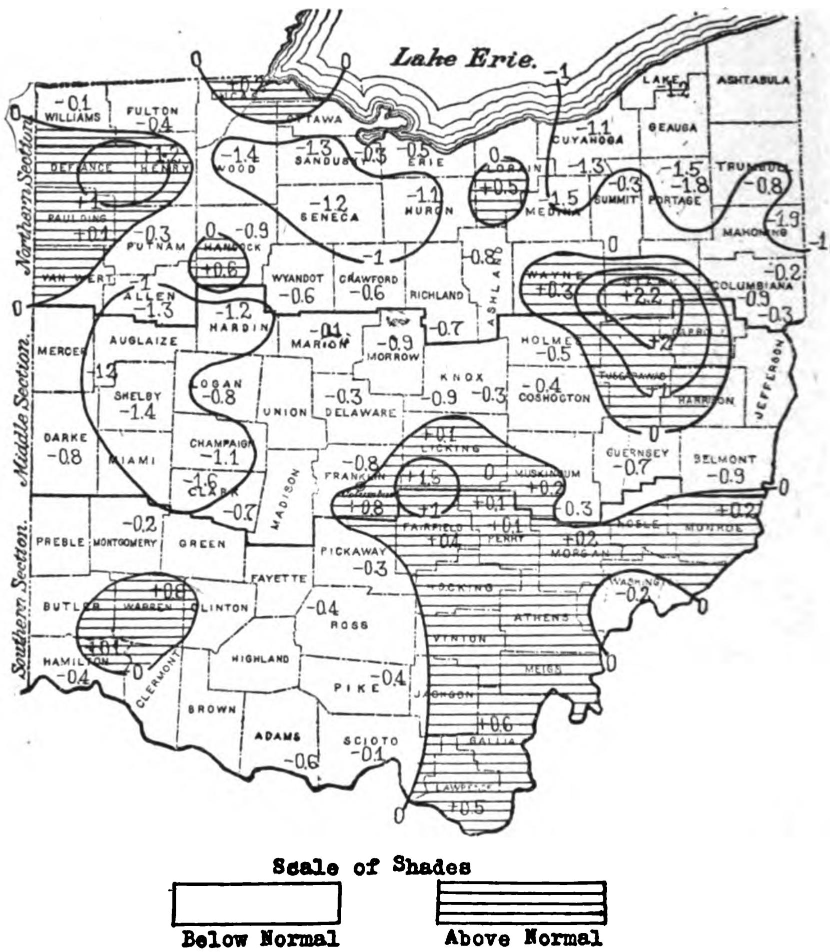


Figure 39. Precipitation departures for September, 1913. The rainfall averaged 0.41 inch below the normal amount for that month. More than the normal amount of rain fell in the southeastern counties, the Tuscarawas valley, and parts of the Maumee and Little Miami valleys. There was an average of 9 rainy days.

Mean temperature, October, 1913

Figure 40. Average temperature for October, 1913. The average temperature for the state as a whole was 54.1°. The highest temperature for the month was 96° at Demos, Belmont county, on the 7th, and the lowest was 18° at Milligan, Perry county, on the 22nd.

The weather was generally warm and pleasant during the first 17 days and cold, wet and disagreeable the remainder of the month. It was unusually warm from the 6th to the 10th, inclusive, the temperature reaching 90° at a number of stations. The coldest periods were the 19th-22nd and 30th-31st. On the 22nd the temperature fell considerably below the freezing point in all parts of the state, bringing the crop season to a close.

Temperature departures, October, 1913

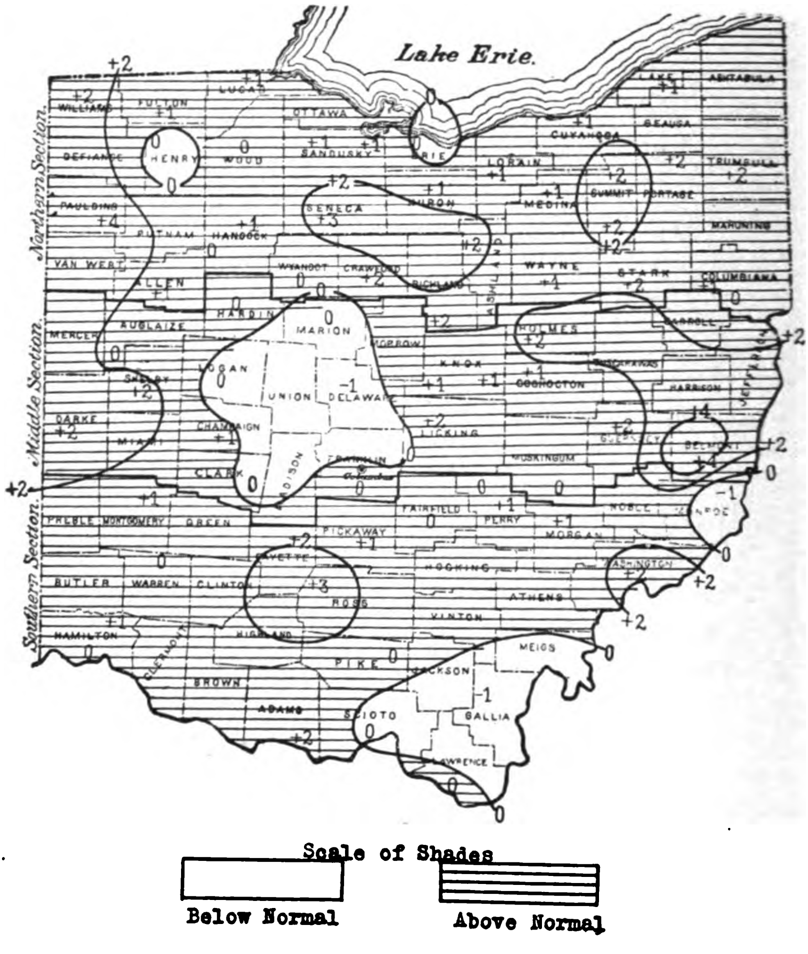


Figure 41. Temperature departures for October, 1913. The average temperature for the state was 1.1° above the normal. The greatest excesses in temperature occurred in northern and eastern counties and the greatest deficiencies occurred in some of the middle and southern counties.

Precipitation, October, 1913

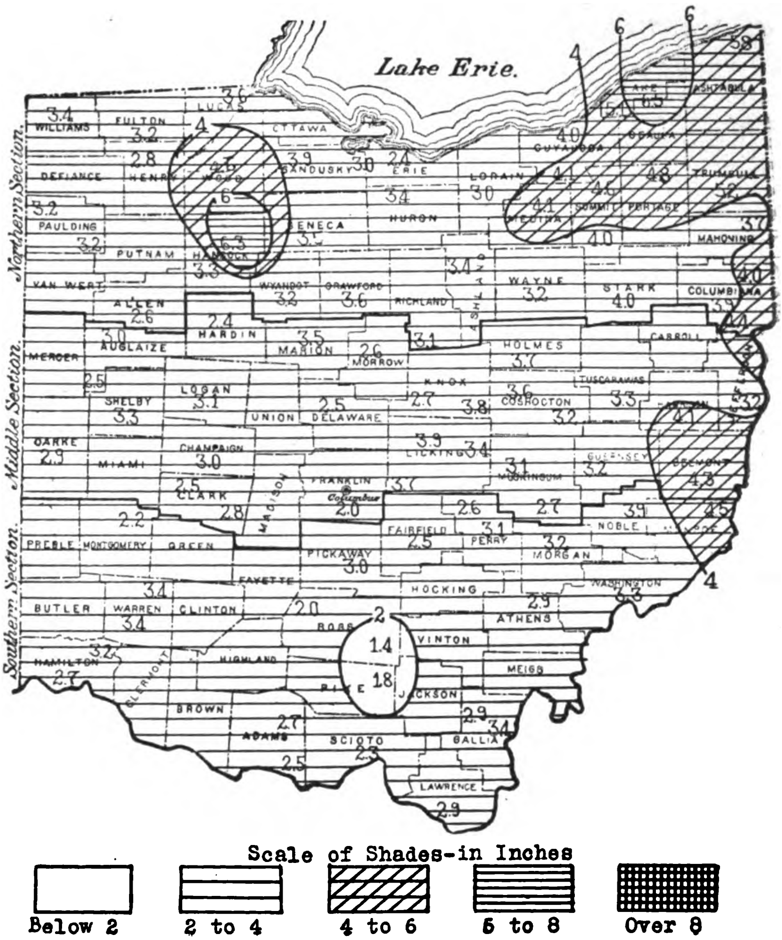


Figure 42. Precipitation for October, 1913. The average precipitation for the state as a whole was 3.36 inches. It was heaviest in northern and extreme eastern counties and lightest in the lower Scioto valley. The monthly totals ranged from 6.51 inches in Lake county to 1.43 inch in Ross county. There were but two rainy periods during the first half of the month and they occurred on the 1st and 2nd, and 11th and 12th. But during the last two weeks rain fell in some part of the state on every day. The average number of rainy days was 12, clear days 10, partly cloudy days 7, and cloudy days 14.

Precipitation departures, October, 1913

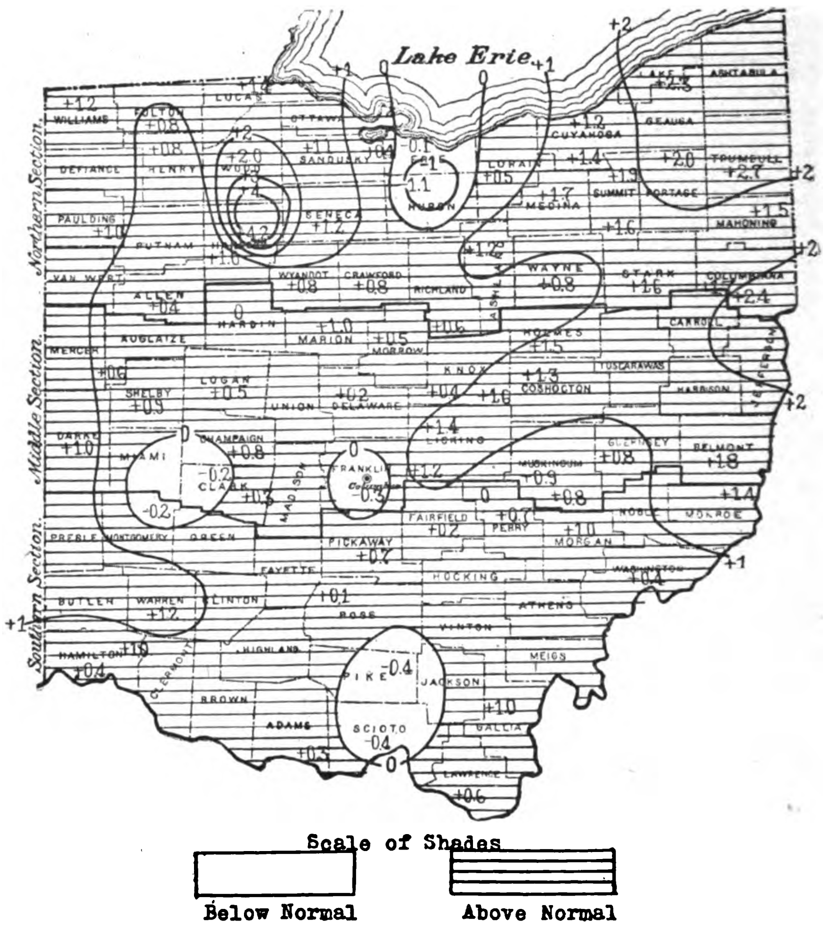


Figure 43. Precipitation departures for October, 1913. The average amount of precipitation for the state was 0.95 inch above the normal. It was above normal at nearly all stations. The greatest excess was 4.2 inches at Findlay and the greatest deficiency was 1.1 inch at Norwalk.

Snowfall, October, 1913

Figure 44. Snowfall for October, 1913. The average snowfall for the state was 0.3 inch. It ranged in amounts from 6.0 inches in Lake county to only flurries in some of the southern counties. Snow fell in the state on the 21st, 22nd, 28th, 30th and 31st.

Mean temperature, November, 1913

Figure 45. Average temperature for November, 1913. This was one of the warmest Novembers in Ohio of which there is record. The mean temperature for the state as a whole was 44.4°. The month opened cool, and with the exception of the 6th and 7th, the temperature was below normal continuously until the 13th. The temperature was above normal continuously during the last 13 days, and during a part of this time it was unseasonably high. The 20th and 22nd were among the warmest November days in Ohio of which there is record. The mean temperature for the 22nd was 29° above the normal at Toledo, 28° above at Cleveland, 25° above at Columbus and 26° above at Cincinnati. The lowest temperature for the month at most stations occurred on the 12th. It was unusually cold on that date for so early in the month, especially in the Muskingum valley, where at 2 stations it fell to 2° above zero.

Temperature departures, November, 1913

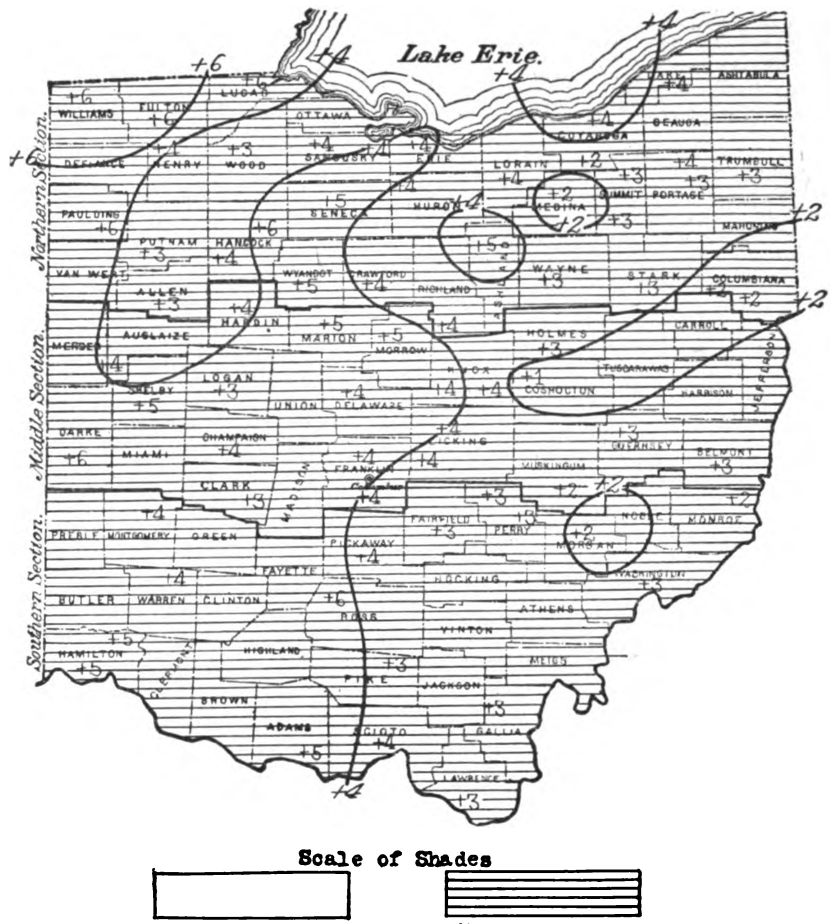


Figure 46. Temperature departures for November, 1913. The temperature for the state averaged 3.7° above normal. In general the greatest excess in temperature occurred along the western border and the least in the middle-eastern counties.

Precipitation, November, 1913

Scale of Shades-in Inches

Below 2	2 to 4	4 to 6	6 to 8	Over 8

Figure 47. Precipitation for November, 1913. The average amount of precipitation for the state as a whole was 3.52 inches. It was heaviest in the southern counties and lightest in a few of the extreme eastern counties and middle-western counties. The monthly totals ranged from 5.21 inches in Harrison county to 1.66 inch in Mahoning county. There was much cloudiness, and precipitation occurred frequently during the last three weeks, especially in the southern districts. The average number of rainy days was 11; clear days, 10; partly cloudy days, 6; cloudy days, 14. Dense fog prevailed on the 27th, 28th and 29th.

Precipitation departures, November, 1913

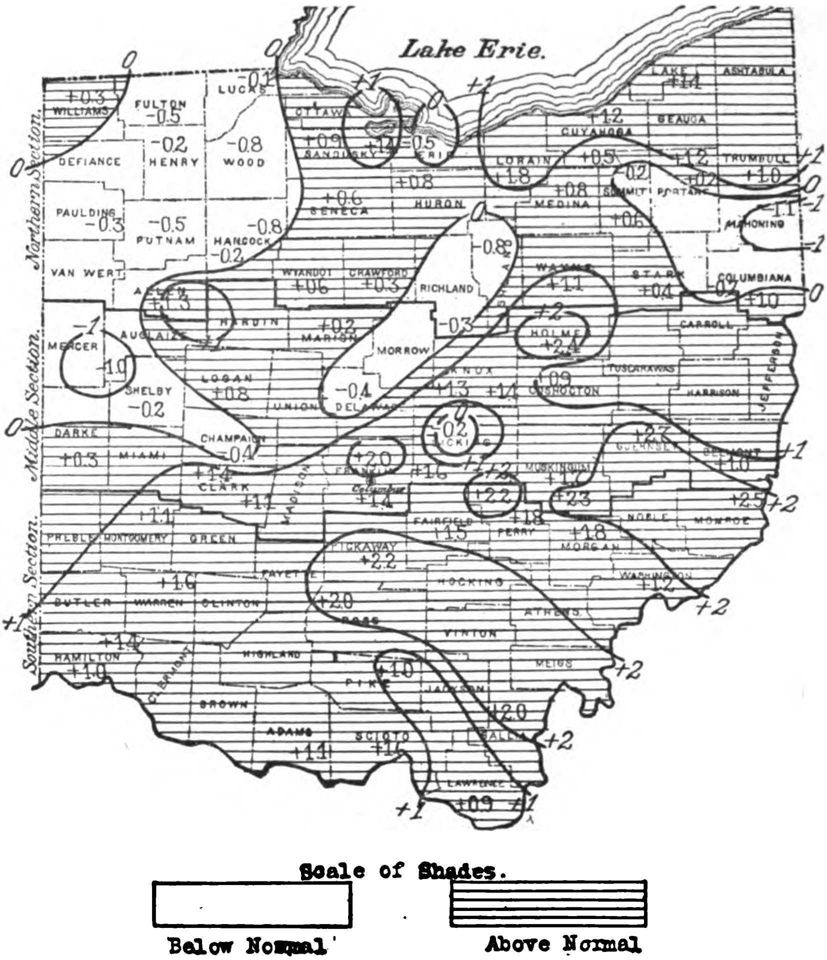


Figure 48. Precipitation departures for November, 1913. The average amount of precipitation for the state was 0.83 inch above normal. The greatest excess was 2.7 inches at Cambridge, Guernsey county, and the greatest deficiency was 1.1 inch at Youngstown, Mahoning county.

Snowfall, November, 1913

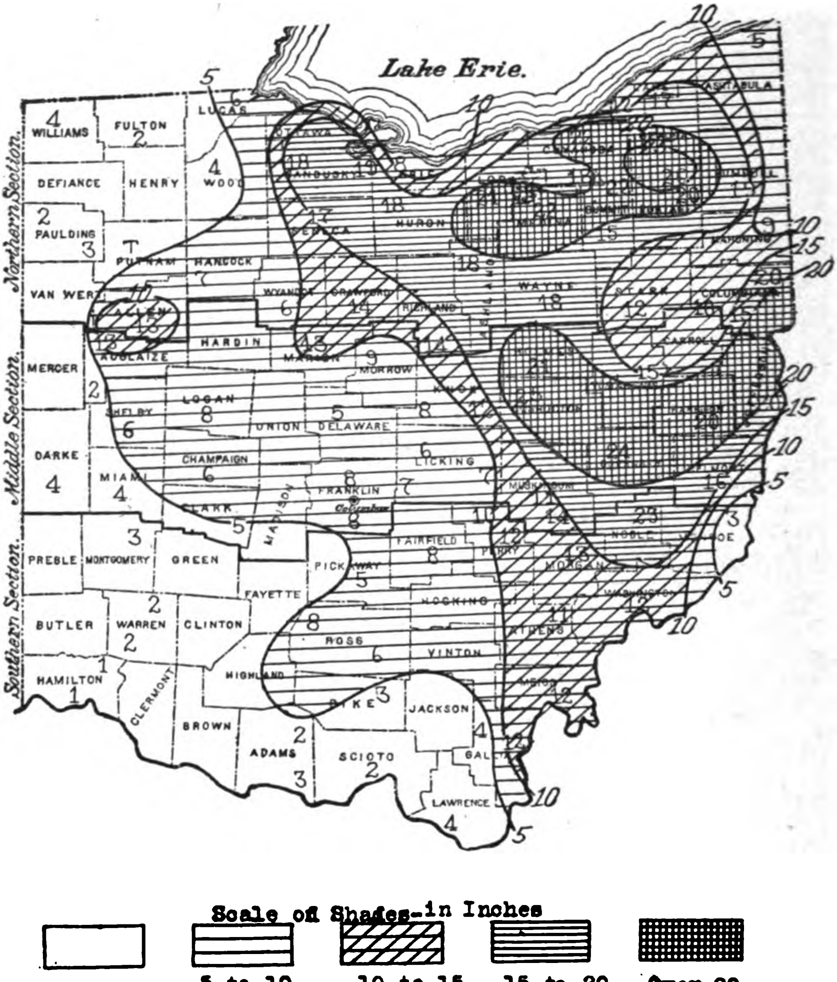


Figure 49. Snowfall for November, 1913. The snowfall was greater than for any other November of which there is record in Ohio. The average for the state was 10.8 inches. It practically all fell during the great snowstorm of the 9th and 10th. In parts of the Cuyahoga and Muskingum valleys the total fall was about 25 inches. It gradually decreased towards the west and in Hamilton county it was only about one inch.

Mean temperature, December, 1913

Figure 50. Average temperature for December, 1913. The month was considerably warmer than usual. The mean temperature for the state as a whole was 34.5°. The temperature was generally above normal during the first 6 days and from the 12th to the 24th, inclusive. It was much above normal on the first 4 days and on the 12th, 13th and 14th. Moderately cold weather was experienced on the 8th and 9th and during the last week; but there were no extremely cold days. The temperature fell to slightly below zero at several places in eastern Ohio on the 28th. There were no sudden temperature changes of importance during the month and the daily changes in temperature were exceptionally small.

Temperature departures, December, 1913

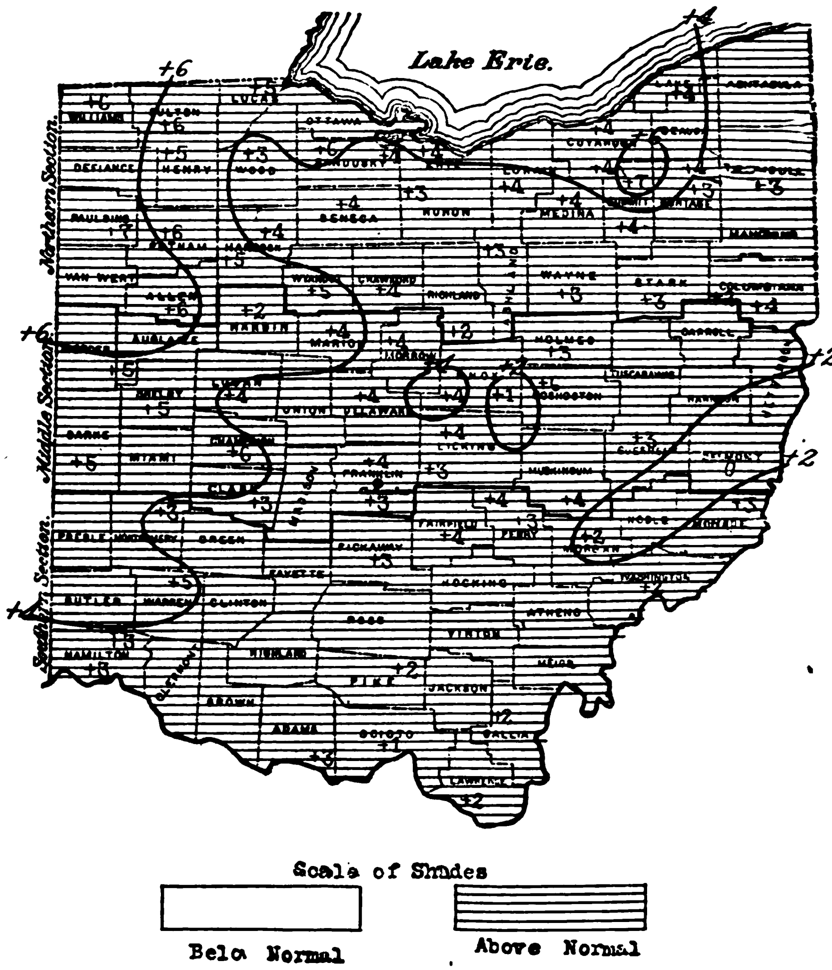


Figure 51. Temperature departures for December, 1913. The temperature for the state as a whole averaged 3.7° above the normal. In general the greatest excess in temperature occurred in northern and western counties, so that the mean temperatures for the stations in the northern part of the state were nearly as high as for those in the extreme southern counties.

Precipitation, December, 1913

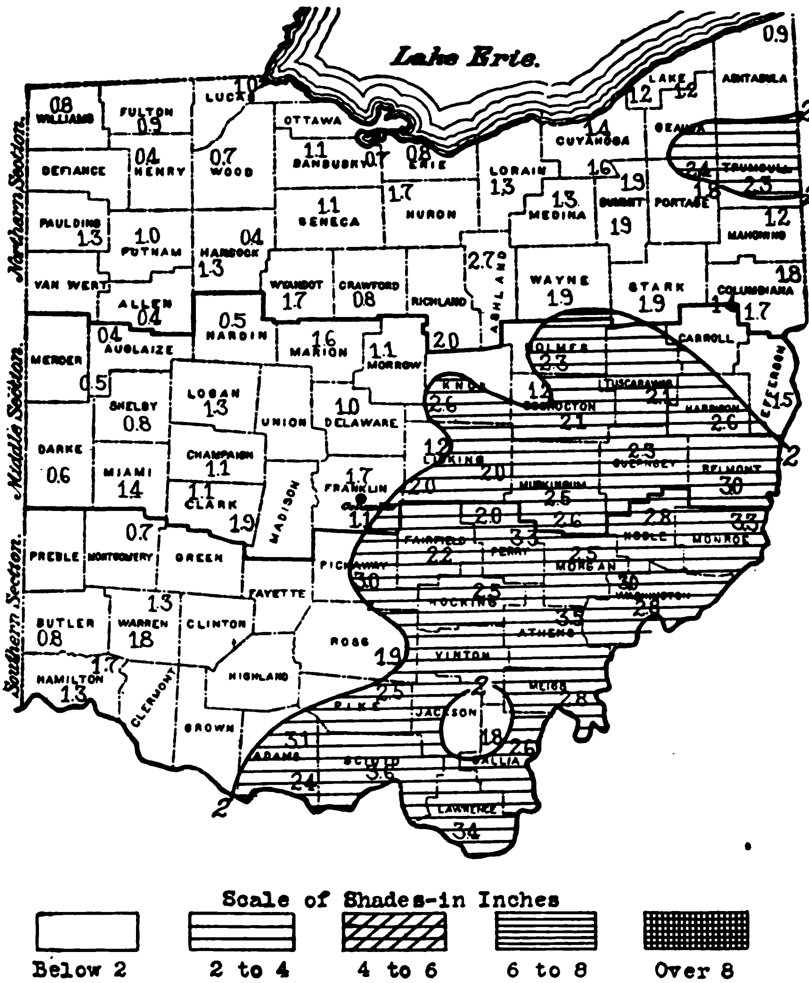


Figure 52. Precipitation for December, 1913. The average amount of precipitation for the state as a whole was 1.68 inch. In general the precipitation was heaviest in the extreme southern and southeastern counties and lightest in the middle western counties. There were no heavy rains during the month and the number of days on which precipitation occurred were fewer than usual.

Precipitation departures, December, 1913

Scale of Shades

Below Normal | Above Normal

Figure 53. Precipitation departures for December, 1913. The average amount of precipitation for the state was 1.16 inch below the normal. The precipitation was deficient at nearly all reporting stations. The greatest excess was 0.6 inch at Circleville, Pickaway county, and Ironton, Lawrence county. The greatest deficiency was 2.7 inches at Lima, Allen county.

Snowfall, December, 1913

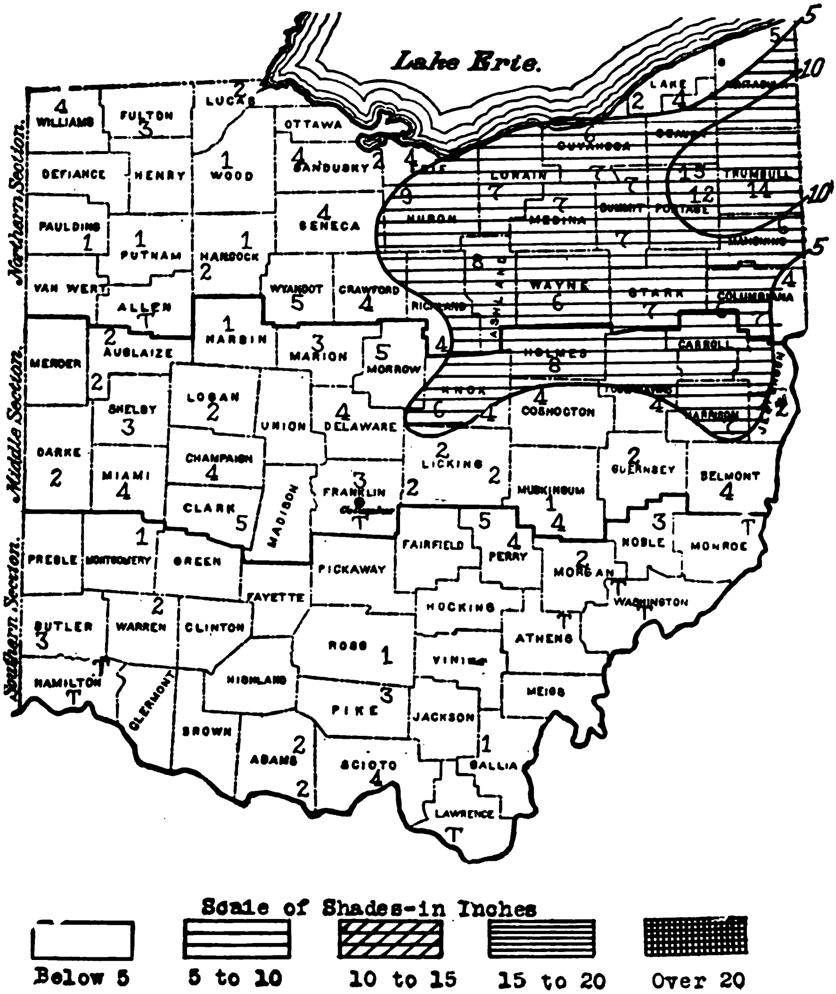


Figure 54. Snowfall for December, 1913. There was less snowfall than usual in nearly all counties. The monthly totals ranged from 15 inches in Portage county to only traces in some of the extreme southern counties. The average for the state as a whole was 3.7 inches. Most of the snow fell on the 7th, 8th, 25th and 26th.

CLIMATOLOGICAL DATA FOR OHIO FOR THE YEAR 1913.

	Monthly mean	Departure from normal	Highest	Date	Lowest	Date	Range	Greatest daily range	Average precipitation	Departure from normal	Average snowfall	Number of rainy days	Number of clear days	Number of partly cloudy days	Number of cloudy days
January	36.0	+7.8	70	20*	3	9	67	42	7.01	+4.17	8.6	17	7	6	18
February	26.7	−0.5	77	21	−15	6	91	50	1.94	−0.77	6.9	8	12	6	10
March	40.1	+0.9	80	14	−8	8	88	58	8.40	+5.28	5.1	13	11	9	11
April	50.0	+0.6	90	25	18	21	72	52	3.35	+0.30	T	10	14	6	10
May	60.3	−0.6	95	4	23	11*	72	54	3.53	−0.12	0	10	14	8	9
June	69.8	+0.6	105	30	29	10	76	48	1.87	−2.04	0	6	20	7	3
July	74.5	+1.0	103	29*	40	11	63	44	5.20	+1.11	0	11	16	12	3
August	73.3	+2.0	102	9	39	25	63	48	2.52	−0.64	0	6	17	10	4
September	64.1	−1.5	102	2	26	23	76	50	2.37	−0.41	T	9	11	7	9
October	54.1	+1.1	96	7	18	22	78	51	3.36	+0.95	0.3	12	10	7	14
November	44.4	+3.7	78	7*	2	12	76	51	3.52	+0.83	10.8	11	10	6	14
December	34.5	+3.7	65	2*	−3	28	67	38	1.68	−1.16	3.7	7	8	6	17

*On other dates also.

METEOROLOGICAL SUMMARY FOR 1913

By C. A. PATTON

EXPLANATION OF TABLES

The following tables contain statistics of temperature, rainfall, etc., for the year, and are compiled from data obtained from daily observations. T stands for "trace"—less than .01 inch of rainfall. Temperature is given in degrees Fahrenheit.

Table I shows the daily rainfall at the Experiment Station at Wooster during the year in inches and hundredths.

Table II shows the daily mean temperature for each day of 1913 and the monthly mean temperature with the 26 years' average.

Table III gives the monthly mean temperature at the station with the 26 years' average for the same.

Table IV gives the monthly mean rainfall at the station with the 26 years' average for the same.

Table V gives the monthly mean temperature for the state for 1913 with 26 years' average.

Table VI gives the monthly mean rainfall for 1913 with the 26 years' average for the state.

Table VII gives the monthly mean temperature and rainfall for the station and state for 1913 with the 26 years' average.

Table VIII contains the mean temperature, the highest and lowest temperatures with the range of temperature for each month; the number of clear, partly cloudy and cloudy days; the rainfall, snowfall and prevailing direction of wind, for both the station and state for 1913.

Table IX contains the principal points of interest on temperature, rainfall, and state of weather at the station during the year, and a grand summary for 26 years.

Table X contains the principal points of interest on temperature, rainfall, and state of weather for the state during the year and a grand summary for 31 years.

Table XI gives the highest and lowest temperature for each month during the past 26 years for both the station and state.

Table XII gives the total and average precipitation at the different district test farms.

Some slight errors in previous publications of tables five, nine and eleven are corrected in this report.

NOTES ON THE WEATHER AT WOOSTER 1913
SUMMARY BY MONTHS

LATITUDE 40° 47′ 01″, LONGITUDE 81° 55′ 48″
ELEVATION ABOVE SEA LEVEL 1,030 FEET

JANUARY

The mean temperature was 34.2° this being 6.6° above the average for this month. The precipitation was more than double the average amount for January, being 7.86 inches. The highest temperature recorded was 57° on the 20th and the lowest was 4° on the 5th. Two heavy snows during the month, both melting off in a few days.

FEBRUARY

The mean temperature was 25.1° which is 1.3° below the average for February. The highest temperature 62° occurred on the 19th. The lowest —2° on the 6th. The precipitation was 2.43 inches, which is slightly below the average for this month. The snowfall for the month amounted to 11.50 inches.

MARCH

The mean temperature for March was above the average, a very severe windstorm on the 21st lasting all day, doing much damage to roofs, fences, etc. Followed on the 23rd by the beginning of the most destructive flood in the history of the county. The rainfall in five days amounting to 10.15 inches. The total precipitation for the month was 11.84 inches, which is 8.10 inches above the average for March.

APRIL

The mean temperature was 48.9 which is slightly above the average for April. The highest temperature 83° occurred on the 25th, the lowest 20° on the 21st. The rainfall was 3.66 inches. This is .65 inch above the average for April. The prevailing wind was from the northwest.

MAY

The mean temperature for May was 58.0, which is 6° below the average for this month. The highest temperature recorded was 86° on the 5th and the lowest was 25° on the 11th. The rainfall was almost one inch below the average.

JUNE

The mean temperature was 67.4°, this is mean for the past twenty-six years for June. Very cold north winds on the 8th and 9th followed by a killing frost on the 10th, doing much damage to corn and early garden truck on low lands. The rainfall was far below the average, being only .97 inch.

JULY

The mean temperature for the month was 72.4° which is 1.° above the average for this month. The rainfall was 4.07 inches, which is very slightly below the average for July. The month was noted for its many extremely warm days, and numerous electrical storms, some rain falling on sixteen days.

AUGUST

The mean temperature for August was 71.5° degrees which is 2.1° above the average. The highest temperature recorded was 96° on the 17th. The lowest was 45° on the 25th. The rainfall was 1.19 inch above the average. The total fall was 4.75 inches.

SEPTEMBER

The mean temperature for September was below the average, the highest 93°, occurred on the 2nd and 3rd, the lowest 28°, on the 23rd. A light frost on the 14th injuring tender plants and vegetation. A killing frost on the 23rd. The total rainfall was 3.70 inches which is .35 inch above the average for September.

OCTOBER

The weather for the first half of October was very fine. The mean temperature was 1° above the average for the month. The total rainfall was 3.17 inches. The highest temperature recorded was 81° on the 6th, 9th and 10th. The lowest 24° occurred on the 22nd.

NOVEMBER

The mean temperature for November was 2.4° above the average for the month. The highest 73° occurred on the 22nd and the lowest 12° on the 12th. A terrific snow blizzard from the northwest and lasting two days and nights without ceasing occurred on the 9th and 10th. The total fall was estimated at 18 inches, drifting to a depth of six or eight feet in places. Roads were impassible for several days. The total precipitation was 3.77 inches.

DECEMBER

The mean temperature was 33.7 which is 3° above the average for December. The highest temperature recorded was 56° on the 2nd. The lowest 7°, on the 28th. The total precipitation was 1.92 inches, which is below the average for this month.

METEOROLOGY—TABLE I—RAINFALL

DAILY RAINFALL AND MELTED SNOW FOR 1913 AT THE EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1	....	....	.20	....	...	.18	.42	....	....	.40	....	.32	1
2	....	....	...	1.04	....	..	.03	....	....	.48	....	....	2
3	.50	.40	....	.04	....	T	....	....	....	.14	....	.02	3
4	.20	....	.35	.60	....	.05	....	.18	T	....	....	....	4
5	.20	....	.07	T	....	....	.50	....	....	....	....	....	5
6	.10	....	.20	....	T	....	.30	....	....	....	....	.05	6
7	.86	....	....	....	....	.02	....	....	T	....	.05	.30	7
8	.52	....	....	....	....	....	....	.06	.03	....	.63	.20	8
9	....	....	T	T	.02	...	.02	....	...	....	1.00	....	9
10	.09	....	T	.24	....	....	....	.45	....	....	.80	T	10
11	.83	T	.10	.17	....	....	....	....	....	.37	T	....	11
12	.40	T	....	....	....	....	.30	.50	....	.03	....	....	12
13	....	....	....	.31	....	....	.58	....	....	....	.50	....	13
14	....	....	....	T	....	....	.39	....	...	....	.40	....	14
15	.02	....	....	.01	.57	....	.04	....	....	....	.03	....	15
16	.62	....	.05	....	....	....	....	....	.18	....	.04	....	16
17	.75	.40	.05	....	....	....	.05	....	2.20	.20	....	....	17
18	.23	....	....	....	....	....	....	1.65	.29	.02	.05	T	18
19	....	....	....	....	....	....	.01	....	....	.15	T	....	19
20	.80	....	....	....	...	.65	.20	....	.60	.26	....	....	20
21	.07	....	.40	....	.10	.05	....	1.35	T	.02	....	.18	21
22	....	.23	....	....	.15	....	....	.50	.12	.06	....	....	22
23	.80	....	1.16	....	.03	....	.20	....	....	T	....	.45	23
24	....	.05	1.94	....	....	....	.07	....	....	.81	....	....	24
25	....	....	4.84	....	....	.02	....	....	....	....	....	.10	25
26	....	.35	1.40	.47	.70	....	...	....	.02	....	.07	.30	26
27	....	.70	.81	.27	1.30	....	.84	....	....	....	T	....	27
28	.60	.30	....	.45	T	....	....	....	....	.05	.10	....	28
29	.02	....	....	.06	T	....	....	.06	.25	.10	.10	....	29
30	....	...	....	....	.17	....	.12	....	.01	.08	T	....	30
31	.25	....	.27	....	....	....	....	....	....	T	....	....	31
Total	7.86	2.43	11.84	3.66	3.04	.97	4.07	4.75	3.70	3.17	3.77	1.92	
Average	.254	.087	.382	.122	.098	.032	.131	.153	.123	.102	.126	.062	

METEOROLOGY—TABLE II—TEMPERATURE

MEAN TEMPERATURE FOR EACH DAY OF 1913, AT THE EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1	31.5	14.0	26.0	45.0	57.5	64.5	81.5	75.5	72.5	63.0	33.0	51.0	1
2	39.0	14.5	15.5	42.5	50.0	61.5	76.5	68.5	75.5	55.0	35.0	50.5	2
3	34.0	26.0	27.5	52.5	76.0	63.0	75.5	71.5	76.5	53.5	42.0	46.5	3
4	22.0	18.0	33.5	56.5	67.0	61.0	86.5	70.5	75.0	55.0	45.0	42.0	4
5	17.0	10.0	21.5	41.0	68.0	57.0	76.0	64.5	74.0	59.0	40.5	43.0	5
6	39.0	6.5	20.5	38.5	67.0	67.5	70.0	67.5	75.5	66.0	44.0	39.0	6
7	35.5	13.0	11.0	33.0	50.0	66.0	60.5	74.0	77.0	64.5	53.5	36.5	7
8	36.5	18.5	28.5	35.5	50.5	50.5	66.0	72.0	71.0	66.5	47.0	23.0	8
9	20.5	20.0	47.5	41.0	52.0	47.5	72.5	80.5	58.5	68.5	32.5	23.0	9
10	28.0	18.0	39.0	49.0	40.5	49.5	67.5	83.0	58.0	68.5	23.5	30.0	10
11	43.0	24.5	38.5	53.0	40.0	54.0	62.0	71.5	60.0	60.5	25.5	31.0	11
12	35.5	14.5	41.5	43.0	46.0	58.0	75.5	69.5	59.5	48.5	27.5	36.0	12
13	23.0	12.0	54.5	42.5	62.0	62.0	76.5	72.5	53.0	45.5	46.0	42.5	13
14	27.5	24.5	64.0	47.0	58.0	66.0	73.0	73.0	50.0	48.5	42.0	41.5	14
15	35.5	33.5	52.5	48.5	56.0	70.5	70.5	78.5	56.5	56.5	30.5	32.5	15
16	44.0	32.5	28.5	50.0	65.0	80.5	68.0	78.0	61.0	61.0	36.5	36.5	16
17	50.0	30.0	26.0	51.0	60.0	75.0	77.0	80.5	66.0	58.0	30.5	37.0	17
18	42.5	27.0	44.0	63.0	64.0	68.5	75.0	79.0	61.5	53.0	44.5	32.5	18
19	35.5	46.5	53.0	55.5	52.0	72.5	72.0	74.0	59.5	43.0	55.5	28.5	19
20	45.0	48.5	59.5	37.0	56.0	76.0	68.0	72.5	64.5	40.0	58.5	31.0	20
21	26.5	44.5	51.5	40.0	67.0	74.0	65.5	73.0	54.5	36.0	58.0	33.0	21
22	29.5	44.5	31.0	60.5	64.5	62.0	66.0	72.0	45.5	35.5	63.0	28.5	22
23	42.5	28.5	37.5	70.0	54.5	65.0	70.5	64.0	45.0	54.5	54.0	31.0	23
24	41.0	18.0	49.5	60.0	55.0	74.5	71.5	63.0	58.0	51.0	40.5	36.0	24
25	35.5	26.0	49.5	64.0	55.5	78.5	62.5	60.5	62.5	50.0	34.5	33.0	25
26	43.0	28.5	45.5	62.0	51.0	81.0	68.5	69.0	62.5	52.0	41.5	29.0	26
27	37.0	33.5	28.5	47.0	58.0	80.5	74.5	68.0	51.0	46.5	43.5	20.5	27
28	25.0	27.5	26.0	42.0	61.0	80.0	80.0	69.0	54.0	43.0	44.5	18.5	28
29	26.0	....	42.5	47.5	60.5	74.5	78.0	72.0	65.0	44.0	47.5	27.0	29
30	37.0	....	52.0	48.0	65.5	82.0	80.5	62.0	71.0	37.5	52.0	25.0	30
31	34.0	....	48.5	....	58.5	....	77.0	66.0	....	34.5	....	29.0	31
Monthly mean	34.2	25.1	38.5	48.9	58.0	67.4	72.4	71.5	62.5	52.2	42.4	33.7	
26-yr. average	27.6	26.4	37.3	48.1	58.6	67.4	71.4	69.4	64.0	51.2	40.0	30.6	

METEOROLOGY—TABLE III

MONTHLY MEAN TEMPERATURE FOR TWENTY-SIX YEARS AT WOOSTER

Temperature in degrees Fahrenheit

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888..........	23.0	28.8	31.7	46.3	57.7	68.9	70.1	67.8	57.1	44.9	40.7	31.4	47.4	1888
1889..........	31.1	22.9	38.7	47.1	57.8	64.5	70.0	66.0	60.8	45.3	39.3	40.7	48.6	1889
1890..........	36.0	36.6	30.9	48.4	56.0	69.8	70.5	65.8	59.6	50.0	41.3	28.8	49.5	1890
1891..........	30.0	34.0	32.0	49.0	52.0	68.0	68.0	71.0	68.0	49.0	38.0	37.0	49.7	1891
1892..........	22.0	33.0	33.0	47.0	57.0	70.0	70.0	69.0	61.0	49.0	38.0	28.0	48.0	1892
1893..........	18.0	28.0	38.8	50.1	57.6	69.3	72.0	67.9	63.2	52.3	37.7	30.9	48.7	1893
1894..........	32.8	26.7	43.5	50.5	57.5	67.9	71.4	69.2	66.1	52.3	36.5	32.9	50.6	1894
1895..........	21.9	17.9	32.4	49.5	59.4	69.9	68.6	70.9	66.5	44.2	40.4	32.8	47.8	1895
1896..........	27.9	29.2	29.8	54.6	64.5	65.6	70.2	68.5	60.6	45.8	44.4	30.6	49.3	1896
1897..........	24.0	30.0	39.3	47.2	53.4	64.3	73.2	67.0	66.7	55.9	40.7	31.8	49.4	1897
1898..........	31.6	27.4	43.3	45.3	58.2	68.7	74.5	71.1	66.2	52.6	38.4	27.9	50.4	1898
1899..........	26.6	21.3	35.0	52.1	60.0	69.4	70.0	71.0	61.6	55.0	43.2	29.0	49.5	1899
1900..........	30.2	25.0	31.8	47.8	61.5	68.5	72.6	74.0	67.1	58.9	40.6	30.7	50.7	1900
1901..........	28.3	20.0	39.1	45.2	57.9	69.1	75.9	71.6	63.3	51.7	36.6	26.1	48.7	1901
1902..........	26.3	21.4	41.2	46.2	61.2	65.6	73.0	66.4	62.7	53.9	47.3	28.7	49.5	1902
1903..........	24.4	29.0	45.7	48.0	62.2	63.0	71.8	68.8	64.4	58.2	36.8	21.7	49.1	1903
1904..........	18.6	20.5	37.6	42.8	59.4	67.0	69.8	66.7	64.2	50.4	39.6	28.1	47.1	1904
1905..........	22.6	19.8	41.2	46.8	59.2	68.0	71.6	70.0	63.8	51.0	38.3	33.1	48.8	1905
1906..........	35.9	25.8	30.2	51.9	59.9	68.8	71.0	74.2	67.7	51.4	40.4	31.2	50.7	1906
1907..........	30.8	24.6	44.9	41.7	52.8	64.6	69.9	68.6	65.0	47.4	38.5	32.1	48.4	1907
1908..........	28.7	26.8	43.1	50.1	62.2	68.1	72.4	69.0	66.4	53.0	41.0	31.7	51.0	1908
1909..........	31.7	33.6	35.9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	50.0	1909
1910..........	26.7	23.8	47.2	50.2	54.7	64.3	72.6	70.9	65.3	54.9	34.8	24.4	49.2	1910
1911..........	31.3	33.8	35.0	46.5	63.5	68.9	71.7	70.6	65.2	51.8	36.7	34.7	50.8	1911
1912..........	16.6	20.5	30.3	50.0	61.1	64.6	71.6	67.1	65.6	52.4	41.0	33.1	47.8	1912
1913..........	34.2	25.1	38.5	48.9	58.0	67.4	72.4	71.5	62.5	52.2	42.4	33.7	50.6	1913
26-yr. av...	27.6	26.4	37.3	48.1	58.6	67.4	71.4	69.4	64.0	51.2	40.0	30.6	49.3	

METEOROLOGY—TABLE IV

MONTHLY RAINFALL FOR TWENTY-SIX YEARS AT WOOSTER

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Date
1888........	3.34	2.43	3.34	2.48	3.82	2.31	4.54	4.35	1.92	3.18	4.95	1.39	38.05	1888
1889........	4.33	2.42	2.13	1.58	2.97	4.86	6.73	1.98	4.05	1.36	3.53	3.93	39.87	1889
1890........	4.71	6.20	4.37	3.10	6.37	4.92	2.67	4.66	5.13	7.45	2.62	1.74	53.94	1890
1891........	2.91	4.83	3.71	1.66	2.24	7.13	3.24	1.85	0.93	1.33	5.73	2.92	38.48	1891
1892........	2.67	2.67	3.38	2.44	7.69	7.89	4.73	2.69	3.20	0.37	2.06	2.74	41.53	1892
1893........	4.01	6.83	1.89	5.66	6.28	2.51	1.38	1.53	1.85	5.15	2.49	1.50	40.58	1893
1894........	2.19	3.37	2.36	1.74	4.41	2.23	1.38	0.76	4.25	2.53	2.41	3.15	30.78	1894
1895........	3.97	0.41	1.98	1.69	1.38	4.20	2.19	2.30	3.92	1.15	4.21	3.51	30.91	1895
1896........	1.73	2.27	3.67	3.34	3.41	3.98	8.05	1.96	5.16	0.71	1.78	3.04	39.10	1896
1897........	3.42	2.64	2.81	2.75	4.97	2.98	3.89	3.86	0.29	0.89	5.76	2.50	36.76	1897
1898........	4.10	2.27	6.44	2.56	4.60	2.70	6.79	5.53	2.15	4.28	4.14	2.29	47.85	1898
1899........	3.29	1.64	3.95	1.28	4.42	1.95	3.73	0.53	5.56	2.21	1.59	2.78	32.93	1898
1900........	2.78	2.74	2.25	1.70	2.23	3.71	5.65	5.97	2.19	2.10	4.30	0.99	36.61	1900
1901........	1.58	1.20	3.09	2.46	4.32	4.82	3.52	3.58	5.64	0.79	1.62	3.47	35.89	1901
1902........	0.63	0.83	2.99	1.55	2.57	5.55	5.26	1.87	3.49	1.52	2.62	4.07	32.95	1902
1903........	3.54	3.69	3.29	4.55	1.59	3.69	4.61	6.58	2.07	2.63	2.25	1.95	40.44	1903
1904........	5.27	3.90	6.22	6.59	4.45	1.67	4.93	2.03	2.27	0.87	0.40	2.68	41.28	1904
1905........	1.83	1.36	2.61	2.51	5.97	7.50	5.14	4.47	5.10	2.32	2.04	2.08	42.93	1905
1906........	1.93	1.06	3.57	2.27	2.98	3.81	4.93	7.38	5.16	3.55	2.39	3.79	42.82	1906
1907........	6.92	1.09	5.80	2.69	3.48	3.81	3.96	2.04	3.13	2.34	1.33	3.41	40.00	1907
1908........	1.96	3.89	5.02	3.64	4.56	2.17	3.44	3.17	0.73	1.22	1.09	3.05	33.94	1908
1909........	2.95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.91	2.55	44.22	1909
1910........	5.29	4.41	0.54	3.22	4.87	2.57	1.12	0.95	2.59	5.24	2.36	2.29	35.45	1910
1911........	4.13	2.25	3.26	3.71	2.45	3.78	3.36	5.19	6.53	5.45	2.50	4.54	47.15	1911
1912........	2.30	1.58	3.77	5.58	5.65	2.21	7.46	7.32	4.41	2.18	1.79	2.35	46.60	1912
1913........	7.86	2.43	11.84	3.66	3.04	0.97	4.07	4.75	3.70	3.17	3.77	1.92	51.18	1913
26-yr. av...	3.45	2.82	3.74	3.01	4.03	3.86	4.25	3.56	3.35	2.54	2.79	2.68	40.06	

METEOROLOGY—TABLE V

MONTHLY MEAN TEMPERATURE FOR TWENTY-SIX YEARS FOR THE STATE

Temperature in degrees Fahrenheit

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888........	24.3	30.5	34.2	49.2	58.8	70.4	72.1	70.4	60.3	47.9	42.9	33.3	49.5	1888
1889........	33.3	25.8	40.2	49.9	60.2	66.7	72.5	69.1	62.9	47.9	41.0	43.8	51.1	1889
1890........	38.8	39.4	34.5	51.3	59.2	73.3	73.0	68.8	62.1	52.7	42.2	31.2	52.2	1890
1891........	33.0	36.0	35.0	52.0	58.0	71.0	69.0	70.0	67.0	51.0	40.0	39.0	51.8	1891
1892........	24.0	35.0	35.0	49.0	59.0	73.0	73.0	71.0	64.0	52.0	38.0	29.0	50.2	1892
1893........	18.0	29.0	38.0	50.2	56.3	70.6	74.5	70.7	65.2	53.7	39.3	32.7	50.0	1893
1894........	33.7	28.9	45.1	50.6	60.0	71.3	74.3	71.2	67.8	53.9	37.5	33.9	52.4	1894
1895........	23.4	19.6	35.5	51.7	61.1	72.0	71.6	73.5	69.0	46.9	41.9	33.9	50.0	1895
1896........	29.4	30.5	32.4	56.9	67.9	69.5	73.2	71.8	62.7	49.0	45.1	32.9	51.8	1896
1897	25.5	32.4	41.5	49.3	56.3	68.1	75.5	69.4	66.9	58.1	42.2	32.8	51.5	1897
1898........	32.4	30.0	45.0	47.2	61.0	71.9	76.0	73.5	67.8	54.1	38.8	28.8	52.2	1898
1899..... ..	27.8	21.6	36.9	53.3	63.3	71.5	74.1	73.7	64.1	57.4	43.9	30.2	51.5	1899
1900........	31.1	26.0	32.9	50.1	62.9	69.8	74.1	76.3	69.3	60.5	41.6	31.6	52.2	1900
1901........	29.2	21.1	39.5	46.7	59.0	70.9	78.1	73.1	64.8	53.8	37.7	27.9	50.2	1901
1902.......	27.3	22.3	41.9	48.2	62.6	66.9	74.0	68.9	63.6	54.6	48.5	29.4	50.7	1902
1903........	27.1	29.9	46.7	49.9	63.9	64.4	72.9	70.7	65.6	54.0	37.2	23.4	50.5	1903
1904........	20.7	22.9	39.7	44.4	60.7	68.4	71.4	68.8	65.5	52.2	40.5	28.0	48.6	1904
1905........	22.7	20.8	42.7	48.5	60.7	69.2	73.0	71.7	65.3	52.6	39.6	32.9	50.0	1905
1906.......	35.7	27.3	31.3	52.1	61.3	69.8	72.1	74.6	68.9	52.7	41.1	32.3	51.6	1906
1907........	32.2	26.0	45.9	42.5	54.5	65.6	72.6	69.5	65.5	48.8	39.1	33.0	49.6	1907
1908........	29.1	27.7	43.4	51.0	62.8	69.2	73.9	71.2	68.0	54.1	41.7	33.1	52.1	1908
1909........	32.2	34.7	37.3	49.1	58.7	70.1	70.7	71.9	63.2	48.8	48.9	25.4	50.9	1909
1910........	27.6	25.5	48.2	51.5	56.0	65.9	73.8	71.4	66.3	56.7	36.3	25.5	50.4	1910
1911........	32.8	34.5	37.4	47.7	66.3	70.9	74.0	72.5	67.5	53.3	37.6	36.3	52.6	1911
1912........	17.9	22.4	32.9	51.9	62.5	66.6	73.4	69.2	67.4	54.8	42.2	33.8	49.6	1912
1913........	36.0	26.7	40.1	50.0	60.3	69.8	74.5	73.3	64.1	54.1	44.4	34.5	52.3	1913
26-yr. av...	28.7	27.9	39.0	49.8	60.6	69.5	73.1	71.4	65.6	52.9	41.1	31.9	51.0	

METEOROLOGY—TABLE VI

MONTHLY RAINFALL FOR TWENTY-SIX YEARS FOR THE STATE

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Date
1888........	3.65	1.74	3.55	1.99	3.77	3.41	4.40	5.16	2.27	3.98	4.25	1.47	39.64	1888
1889........	3.13	1.35	1.38	1.79	3.71	4.13	4.19	1.50	3.62	1.78	4.02	2.81	33.41	1889
1890........	4.94	5.25	5.29	3.45	5.52	4.50	1.99	4.66	5.56	4.27	2.53	2.37	50.33	1890
1891........	2.82	4.91	4.19	2.13	2.20	4.82	3.82	3.07	1.50	1.76	5.00	2.39	38.61	1891
1892........	2.11	3.03	2.86	3.32	6.32	5.61	3.80	2.99	2.36	0.73	2.32	1.71	37.16	1892
1893........	2.56	5.13	2.09	6.37	4.97	3.34	2.49	2.17	1.57	4.24	2.09	2.61	39.63	1893
1894........	2.14	2.79	2.16	2.31	4.00	2.65	1.56	1.67	3.31	2.01	2.17	2.98	29.75	1894
1895........	4.00	0.69	1.59	2.11	1.80	2.47	2.00	2.96	1.66	1.22	4.11	3.85	28.46	1895
1896........	1.67	2.21	3.34	2.78	2.67	4.81	8.11	3.38	5.13	1.20	2.63	1.65	39.58	1896
1897........	1.93	3.64	5.17	3.27	3.93	2.85	4.65	2.72	0.78	0.64	6.62	2.39	38.59	1897
1898........	5.25	2.32	6.23	2.38	4.10	2.86	3.98	4.50	2.56	3.72	3.17	2.71	43.78	1898
1899........	3.01	2.11	4.64	1.61	4.32	2.94	4.17	1.82	2.68	2.14	1.72	3.16	34.32	1899
1900........	2.37	3.46	2.35	1.89	2.40	3.01	4.62	3.68	1.76	1.89	4.15	1.24	32.82	1900
1901........	1.70	1.24	2.66	3.40	3.96	4.44	2.72	3.33	2.86	0.73	1.53	3.79	32.36	1901
1902........	1.42	0.88	2.76	2.21	3.09	7.48	4.69	1.67	4.55	2.28	2.60	3.95	37.58	1902
1903........	2.36	4.95	3.51	4.01	2.82	4.02	3.67	3.20	1.52	2.62	2.10	2.07	36.85	1903
1904........	3.85	2.69	5.67	3.53	3.79	2.88	4.13	2.74	1.95	1.50	0.37	3.09	36.19	1904
1905........	1.73	1.58	2.50	3.10	5.63	4.72	3.93	4.46	2.86	3.65	2.63	2.29	39.08	1905
1906........	1.98	1.16	3.97	1.89	2.17	3.42	5.14	4.77	2.92	3.19	2.59	3.68	36.88	1906
1907........	6.06	0.85	5.55	2.74	3.47	4.57	5.36	2.48	3.92	2.76	1.93	3.16	42.85	1907
1908........	1.82	4.10	5.43	3.71	4.72	2.51	4.08	2.59	0.58	1.17	1.06	2.33	34.10	1908
1909........	3.24	5.39	2.77	4.13	4.72	5.86	3.76	3.56	1.78	2.31	2.52	2.62	42.66	1909
1910........	4.48	4.05	0.26	3.49	3.30	2.66	3.17	1.58	4.05	4.19	1.89	2.41	36.03	1910
1911........	3.90	1.95	2.33	4.35	1.69	3.92	2.40	5.39	4.87	4.99	2.91	3.93	42.63	1911
1912........	2.12	2.08	4.17	4.47	3.12	3.17	5.70	4.08	3.11	2.44	1.10	2.26	37.82	1912
1913........	7.01	1.94	8.40	3.35	3.53	1.87	5.20	2.52	2.37	3.36	3.52	1.68	44.75	1913
26-yr. av...	3.13	2.75	3.65	3.07	3.70	3.80	3.99	3.18	2.77	2.49	2.75	2.64	37.92	

METEOROLOGY—TABLE VII

MEAN TEMPERATURE AND RAINFALL AT THE STATION AND FOR THE STATE, 1913, AND FOR TWENTY-SIX YEARS

Temperature in degrees Fahrenheit. Rainfall in inches

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mean temperature at the Station, 1913	34.2	25.1	38.5	48.9	58.0	67.4	72.4	71.5	62.5	52.2	42.4	33.7	50.6
Twenty-six years' average temperature at the Station	27.6	26.4	37.3	48.1	58.6	67.4	71.4	69.4	64.0	51.2	40.0	30.6	49.3
Mean temperature for the State, 1913	36.0	26.7	40.1	50.0	60.3	69.8	74.5	73.3	64.1	54.1	44.4	34.5	52.3
Twenty-six years' average temperature for the State	28.7	27.9	39.0	49.8	60.6	69.5	73.1	71.4	65.6	52.9	41.1	31.9	51.0
Rainfall at the Station, 1913	7.86	2.43	11.84	3.66	3.04	0.97	4.07	4.75	3.70	3.17	3.77	1.92	51.18
Twenty-six years' average rainfall at the Station	3.45	2.82	3.74	3.01	4.03	3.86	4.25	3.56	3.35	2.54	2.79	2.68	40.08
Rainfall for the State, 1913	7.01	1.94	8.40	3.35	3.53	1.87	5.20	2.52	2.37	3.36	3.52	1.68	44.75
Twenty-six years' average rainfall for the State	3.13	2.75	3.65	3.07	3.70	3.80	3.99	3.18	2.77	2.49	2.75	2.64	37.92

METEOROLOGY—TABLE VIII

SUMMARY BY MONTHS FOR 1913

	Temperature											Number of days				Precipitation in inches			
AT THE STATION	Mean	Highest	Date	Lowest	Date	Range	Mean daily range	Greatest daily range	Date	Least daily range	Date	Clear	Partly cloudy	Cloudy	Rainfall .01 or more	Monthly rainfall	Average daily rainfall	Monthly snowfall	Prevailing wind
January	34.2	57	20	4	5	53	18.2	37	8	6	*4	4	3	24	19	7.86	.254	15.25	S. W.
February	25.1	62	19	−2	6	64	18.9	32	18	5	28	11	5	12	7	2.43	.087	11.50	S. W.
March	38.5	74	14	1	7	73	21.2	35	15	9	2	13	3	15	14	11.84	.382	6.25	S. W.
April	48.9	83	25	20	21	63	23.4	40	21	8	28	10	7	13	11	3.66	.122	T	N. W.
May	58.0	86	5	25	11	61	25.3	46	15	13	23	18	4	9	8	3.04	.098	.....	N. W.
June	67.4	96	30	32	10	64	30.3	41	6	17	8	26	2	2	6	.97	.032	.....	S. W.
July	72.4	95	*1	42	11	53	25.8	40	11	15	24	19	11	1	16	4.07	.131	.....	S. W.
August	71.5	96	17	45	25	51	27.0	35	*2	14	22	22	8	1	8	4.75	.153	.....	S. W.
September	62.5	93	*2	28	23	65	25.4	44	11	9	*18	16	5	9	9	3.70	.123	.....	S. W.
October	52.2	81	*6	24	22	57	19.1	39	14	4	28	11	3	17	15	3.17	.102	.50	S. W.
November	42.4	73	22	12	12	61	18.1	40	6	5	*26	8	4	18	12	3.77	.126	18.00	S. W.
December	33.7	56	2	7	28	49	13.9	27	15	4	24	8	4	19	9	1.92	.062	6.50	S. W.
Sums and averages	50.6	96	June *30	−2	Feb. 6	98	22.2	38	May 15	4	Oct. 28	166	59	140	134	51.18	.139	58.00	S. W.
FOR THE STATE																			
January	36.0	70	*20	3	9	67	....	42	..	..	..	7	6	18	17	7.01	.230	8.6	S. W.
February	26.7	77	21	−15	6	92	....	50	..	..	..	12	6	10	8	1.94	.070	6.9	S. W.
March	40.1	80	14	−8	8	88	....	58	..	..	..	11	9	11	13	8.40	.270	5.1	S. W.
April	50.0	90	25	18	21	72	...	52	..	..	..	14	6	10	10	3.35	.112	T	N. W.
May	60.3	95	4	23	*11	72	....	54	..	..	..	14	8	9	10	3.53	.113	....	S. W.
June	69.8	105	30	29	10	76	...	48	..	..	..	20	7	3	6	1.87	.062	....	S. W.
July	74.5	103	*29	40	11	63	....	44	..	..	..	16	12	3	11	5.20	.168	....	S. W.
August	73.3	102	9	39	25	63	....	48	..	..	..	17	10	4	6	2.52	.081	....	S. W.
September	64.1	102	2	26	23	76	....	50	..	..	..	14	7	9	9	2.37	.079	T	S. W.
October	54.1	96	7	18	22	78	....	51	..	..	..	10	7	14	12	3.36	.109	0.3	S. W.
November	44.4	78	*7	2	12	76	....	51	..	..	..	10	6	14	11	3.52	.117	10.8	S. W.
December	34.5	65	2	−3	28	68	....	38	..	..	..	8	6	17	7	1.68	.055	3.7	S. W.
Sums and averages	52.3	105	June 30	−15	Feb. 6	120	....	49	..	..	..	153	91	121	119	44.75	.122	35.4	S. W.

*On other dates also.

METEOROLOGY—TABLE IX

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-SIX YEARS AT WOOSTER

	1888	1889	1890	1891	1892	1893	1894	1895	1896
AT........................	WOOSTER					EXPERIMENT STATION			
Mean temperature	47.4°	48.6°	49.5°	49.7°	48°	48.7°	50.6°	47.8°	49.3°
Highest temperature	....	91.5° *1	94.5° Aug. 3	99° Aug. 8	98° July 25	95° *5	98° July 19	98° June 4	93° Aug. 9
Lowest temperature	−5° Feb. 9	−5° *2	1° Mar. 2	0° Mar. 1	−20° Jan. 20	−9° Jan. 11	−7° Dec. 28	−6° *8	−6° Feb. 19
Range of temperature	....	96.5°	93.5°	99°	118°	104°	105°	104°	99°
Mean daily range of temperature	....	18.7°	18.9°	21°	19°	20.2°	22.9°	21.8°	19°
Greatest daily range of temperature	....	42° Apr. 23	41° Jan. 13	42° Sept. 23	46° July 17	45° Aug. 9	45° July 31	55° Oct. 6	43° May 8
Least daily range of temperature	....	2° Jan. 6	4.5° *3	4° Feb. 8	4° *4	3° *6	4° *7	1° Nov. 22	3° *9
Number of clear days	....	125	109	133	123	98	127	125	130
Number of partly cloudy days	....	103	119	117	132	164	154	117	106
Number of cloudy days	....	137	137	115	111	105	84	123	130
Number of days rain fell	....	119	149	119	119	129	130	102	134
Total yearly rainfall	38.05 inches	39.87 inches	53.94 inches	38.48 inches	41.53 inches	40.58 inches	30.78 inches	30.91 inches	39.10 inches
Greatest monthly rainfall	4.95 inches	6.73 in. July	7.45 in. Oct.	7.13 in. June	7.89 in. June	6.33 in. Feb.	4.41 in. May	4.21 in. Nov.	8.05 in. July
Least monthly rainfall	1.39 inch	1.36 in. Oct.	1.74 in Dec.	0.93 in. Sept.	0.37 in. Oct.	1.38 in. July	0.76 in. Aug.	0.41 in. Feb.	0.71 in. Oct.
Prevailing direction of wind	S.	S.	S.	S.	S. W.	S. W.	S. W.	W.	S. W.

*1 July 10 and Sept. 1. *2 Feb. 23 and 24. *3 Jan. 8 and Sept 10. *4 March 5, Nov. 1, 3 and 25, Dec. 1 and 18. *5 July 7, 25 and Sept. 7. *6 Jan. 24, Feb. 11, May 26. *7 Dec. 1 and 21. *8 Jan. 12, 13 and Feb. 5. *9 Jan. 10 and March 8.

METEOROLOGY—TABLE IX. Continued

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-SIX YEARS AT WOOSTER

	1897	1898	1899	1900	1901	1902	1903	1904	1905
AT	EXPERIMENT STATION								
Mean temperature	49.4°	50.4°	49.5°	50.7°	48.7°	49.5°	49.1°	47.1°	48.8°
Highest temperature	96° *10	96° July 3	96° Aug. 20	95° July 4	95° *12	97° May 4	94° *14	92° July 17	92° July 17
Lowest temperature	−18° Jan. 26	−9° Feb. 2	−21° Feb. 10	−10° Feb. 27	−11° Dec. 21	−9° Feb. 5	−9° Feb. 19	−21° Jan. 5	−12° Feb. 14
Range of temperature	114°	105°	116°	105°	106°	106°	103°	113°	104°
Mean daily range of temperature	21.5°	20.3°	22.9°	20.6°	20.1°	21.3°	21.6°	21.5°	20.8°
Greatest daily range of temperature	49° Oct. 5	50° Nov. 14	52° Oct. 24	43° May 6	43° April 30	45° May 4	48° Nov. 8	48° Dec. 28	42° *16
Least daily range of temperature	0° Feb. 6	5° *11	3° Feb. 18	2° Nov. 20	2° April 20	4° *13	3° *15	0° Dec. 25	2° Dec. 18
Number of clear days	124	133	126	149	152	183	148	149	144
Number of partly cloudy days	123	104	114	101	66	49	58	47	44
Number of cloudy days	118	128	125	116	147	133	159	170	177
Number of days rain fell	123	134	116	132	142	140	121	136	118
Total yearly rainfall	36.76 inches	47.85 inches	32.93 inches	36.61 inches	35.89 inches	32.95 inches	40.44 inches	41.28 inches	42.93 inches
Greatest monthly rainfall	5.76 in. Nov.	6.79 in. July	5.56 in. Nov.	5.97 in. Aug.	5.64 in. Nov.	5.55 in. June	6.58 in. Aug.	6.59 in. Apr.	7.50 in. June
Least monthly rainfall	0.29 in. Sept.	2.15 in. Sept.	0.53 in. Aug.	0.99 in. Dec.	0.79 in. Oct.	0.63 in. Jan.	1.59 in. May	0.40 in. Nov.	1.36 in. Feb.
Prevailing direction of wind	S. W.	N. W.	N. S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S

*10 July 5 and 6. *11 Jan. 21, March 2 and Dec. 18. *12 July 1, 22 and 28. *13 Jan. 22 and April 28. *14 July 4 and 9. *15 Jan. 4, Nov. 27 and Dec. 6.
*16 April 9 and May 2.

METEOROLOGY—TABLE IX. Concluded

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-SIX YEARS AT WOOSTER

	1906	1907	1908	1909	1910	1911	1912	1913	Summary for 26 years
AT....	EXPERIMENT STATION								
Mean temperature	50.7°	48.4°	51.0°	50.0°	49.2°	50.8°	47.8°	50.6°	49.3°
Highest temperature	92° June 9	90° Aug. 12	95° *17	90° Sept. 14	94° *19	101° July 4	93° Sept. 10	96° *20	101° July 4, '11
Lowest temperature	−14° Feb. 7	−14° Jan. 20	−3° Feb. 9	−11° Jan. 13	−12° Feb. 19	−11° Jan. 4	−24° Jan. 13	−2° Feb. 6	−24° Jan. 13 '12
Range of temperature	106°	104°	98°	101°	106°	112°	117°	98°	125°
Mean daily range of temperature	20.6°	20.8°	23°	21.4°	23.1°	21.5°	21.4°	22.2°	21°
Greatest daily range of temperature	40° April 18	42° Jan. 20	49° Sept. 18	43° *18	51° April 14	45° Mar. 25	43° Feb. 13	46° May 15	55° Oct. 6, '95
Least daily range of temperature	2° Jan. 18	4° Aug. 6	5° Dec. 13	3° Dec. 14	3° Nov. 16	4° Mar. 28	6° Jan. 23	4° *21	0° *22
Number of clear days	130	109	141	114	127	111	140	166	132
Number of partly cloudy days	60	58	78	76	67	83	78	59	91
Number of cloudy days	175	198	147	175	171	171	148	140	142
Number of days rain fell	142	138	117	144	133	142	124	134	129
Total yearly rainfall	42.82 inches	40.00 inches	33.94 inches	44.22 inches	35.45 inches	47.15 inches	46.60 inches	51.18 inches	40.08 inches
Greatest monthly rainfall	7.38 in. Aug	6.92 in. Jau.	5.02 in. Mar.	6.44 in. Jan.	5.29 in. Jan.	6.53 in. Sept.	7.46 in. July	11.84 in. Mar.	11.84 in. Mch '13
Least monthly rainfall	1.06 in. Feb.	1.09 in. Feb.	0.73 in. Sept.	1.73 in. Sept.	0.54 in Mar.	2.25 in. Feb.	1.58 in. Feb.	.97 in. June	.29 in. Sept., '97
Prevailing direction of wind	S.	N. S. W	S. W.	S. W.	S. W.	N. W	S. W.	S. W.	S. W.

*17 Aug. 3, Sept. 24 and 25. *18 May 8 and Oct. 9. *19 July 25 and Aug. 15 and 16. *20 June 30 and Aug. 17. *21 Oct. 28 and Dec. 24 *22 Feb. 6, 1897, and Dec. 25, 1904.

METEOROLOGY—TABLE X

SUMMARY BY YEARS AND GRAND SUMMARY FOR THIRTY-ONE YEARS FOR THE STATE

FOR THE STATE	1883	1884	1885	1886	1887	1888	1889	1890
Mean temperature	49.4°	50.6°	48.0°	49.6°	52.0°	49.5°	51.1°	52.2°
Highest temperature	98° Aug. 22	102° Sept. 28	101° July 21	98.6° July 18	108° July 18	102° Aug. 3	99.5° Aug. 31	103.1° Aug. 3
Lowest temperature	—18° Jan. 22	—34° Jan. 25	—31° Jan. 29	—21.5° Jan. 12	—21° Jan. 7	—15° Jan. 27	—13.5° Feb. 24	—4° Mar. 7
Range of temperature	115.5°	133°	132°	120.1°	29°	117°	113°	107.1°
Greatest daily range of temperature	55.2° Mar. 18	50° *2	58.5° Jan. 30	57° Dec. 11	57° Dec. 11	50°	53° Mar. 30	48.5 Apr. 11
Average number of days rain fell	146	145	148	131	121	125	118	149
Mean yearly rainfall	44.98 inches	36.19 inches	38.06 inches	36.71 inches	33.63 inches	39.64 inches	33.41 inches	50.33 inches
Mean daily rainfall	.123 inch	.099 inch	.104 inch	.101 inch	.092 inch	.108 inch	.092 inch	.138 inch
Prevailing direction of wind	S. W.......	S. W.......	S. W	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......

	1891	1892	1893	1894	1895	1896	1897	1898
Mean temperature	51.8°	50.2°	50.0°	52.4°	50.0°	51.8	51.5°	52.2
Highest temperature	101° Aug. 10	103° July 25	102° June 19	105° *4	106° July 20	103° Apr. 17	113° July 4	105° July 1
Lowest temperature	—5° Mar. 5	—27° Jan. 20	—24° Jan. 11	—27° Dec. 29	—24° Feb. 6	—18° *6	—27° Jan. 26	—20° Feb. 3
Range of temperature	109°	128°	126°	132°	130°	121°	140°	125°
Greatest daily range of temperature	50° *3	51° Sept. 25	54.6°	60° Oct. 19	59° *5	53° Mar. 25	67° *7	....
Average number of days rain fell	120	121	113	100	89	124	110	121
Mean yearly rainfall	38.61 inches	37.16 inches	39.63 inches	29.75 inches	28.46 inches	39.58 inches	38.59 inches	43.78 inches
Mean daily rainfall	.106 inch	.102 inch	.109 inch	.081 inch	078 inch	.108 inch	.106 inch	.119 inch
Prevailing direction of wind	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......

*1 Sept. 28. *2 Sept. 5 and Dec. 4. *3 April 27 and 30. *4 July 18 and 19. *5 Jan. 15 and March 29. *6 Feb. 20 and 21. *7 Sept. 25 and 26.

METEOROLOGY—TABLE X. Concluded

SUMMARY BY YEARS AND GRAND SUMMARY FOR THIRTY-ONE YEARS FOR THE STATE

FOR THE STATE	1899	1900	1901	1902	1903	1904	1905	1906
Mean temperature	51.5°	52.2°	50.2°	50.7°	50.5°	48.6°	50.0°	51.6
Highest temperature	107° Sept 6	103° *8	109° July 22	100° July 8	104° July 25	99° *10	100° July 10	101° Aug. 21
Lowest temperature	—39° Feb. 10	—20° *9	—20° Feb. 23	—17° Feb. 14	—20° Feb. 19	—30° Jan. 4	—22° Feb. 3	—23° Feb. 6
Range of temperature	144°	123°	129°	117°	124°	129°	120°	124°
Greatest daily range of temperature	....	57° Feb. 9	61° Dec. 14	56° May 4	60° Sept. 25	54° Jan. 5	57° May 24	54° Oct. 13
Average number of days rain fell	107	107	107	114	111	117	118	124
Mean yearly rainfall	34.32 inches	32.82 inches	32.36 inches	37.58 inches	36.85 inches	36.19 inches	39.08 inches	36.88 inches
Mean daily rainfall	.094 inch	.090 inch	.089 inch	.103 inch	.101 inch	.099 inch	.107 inch	.101 inch
Prevailing direction of wind	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......
	1907	**1908**	**1909**	**1910**	**1911**	**1912**	**1913**	**Summary for 31 years**
Mean temperature	49.6°	52 1°	50.9°	50.4°	52.6°	49.6°	52.3°	50.8°
Highest temperature	98° July 22	104° Aug. 3	97° July 30	100° Aug. 17	107° July 4	101° July 15	105° June 30	113° July 4 '97
Lowest temperature	—23 Jan. 6	—22° Feb. 9	—20° Dec. 30	—25° Feb. 19	—19° Jan. 4	—37° Jan. 13	—15° Feb. 6	—39° Feb. 10, '99
Range of temperature	117°	126°	117°	125°	126°	138°	120°	152°
Greatest daily range of temperature	57° Feb. 13	60° Oct. 5	51°	....	....	....	....	....
Average number of days rain fell	129	111	124	112	127	112	120	120
Mean yearly rainfall	42.86 inches	34.10 inches	42.65 inches	36.03 inches	42.63 inches	37.82 inches	44.75 inches	37.92 inches
Mean daily rainfall	.117 inch	.093 inch	.117 inch	.099 inch	.117 inch	.104 inch	.123 inch	.104 inch
Prevailing direction of wind	S. W.......	S. W.	S. W.......	S. W.......	S. W.......	S. W.......	S. W.......	S. W........

*8 July 4, Aug. 6 and 10. *9 Jan. 20 and Feb. 27. *10 July 17 and Sept. 29.

METEOROLOGY TABLE XI

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-SIX YEARS AT WOOSTER

Date	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	..	-5	..	-1	..	8	..	19	..	31	..	42	..	43	..	41	..	31	..	27	..	21	..	9
1889	54	12	54	-5	71	16	80	21	90	30	87	38	92	49	90	45	92	37	76	23	65	16	65	18
1890	66	5	65	14	60	1	74	23	83	30	88	46	94	45	95	40	88	38	81	30	66	24	48	15
1891	51	12	60	3	61	0	83	21	82	28	89	44	89	49	99	53	98	42	88	25	71	10	58	16
1892	54	-20	54	6	65	10	76	28	86	38	90	56	98	48	92	49	88	36	81	25	67	16	61	-2
1893	51	-9	47	-2	75	10	83	24	84	36	92	45	95	47	93	37	95	28	85	24	66	15	62	6
1894	56	1	64	-1	75	14	92	24	83	35	93	37	98	41	96	41	93	36	80	28	65	31	57	-7
1895	54	-6	60	-6	59	9	80	21	94	27	98	35	92	42	94	42	93	34	73	19	72	18	61	-2
1896	53	-2	58	-6	65	4	89	19	86	44	87	39	92	45	93	41	92	34	71	21	69	13	56	1
1897	61	-18	54	0	69	11	79	21	78	31	88	37	96	50	92	42	96	28	86	25	65	12	60	2
1898	64	-1	64	-9	71	12	77	16	81	32	90	40	96	45	90	46	90	38	86	24	66	13	56	1
1899	55	-6	57	-21	67	9	86	21	86	30	92	40	94	45	95	39	94	32	92	22	66	22	63	-2
1900	54	-5	65	-10	57	-4	78	20	89	25	90	44	95	44	94	49	89	41	86	30	69	6	55	11
1901	53	-4	40	0	69	-1	82	22	82	33	91	38	95	50	94	47	86	34	79	26	67	18	64	-11
1902	47	2	59	-9	69	9	83	24	97	29	89	39	93	46	88	40	85	32	77	27	72	24	60	-5
1903	60	-8	63	-9	76	21	74	19	89	27	88	41	94	42	92	43	89	32	79	26	71	9	49	-2
1904	60	-21	57	-10	74	13	72	12	88	33	88	44	92	46	90	42	89	31	83	19	68	15	63	-1
1905	59	-8	43	-12	79	10	77	23	82	31	89	38	92	50	90	46	87	36	80	23	61	16	52	13
1906	72	6	65	-14	61	-5	80	21	86	29	92	47	88	46	91	48	90	44	74	22	72	23	58	6
1907	67	-14	50	-5	82	12	78	15	81	29	89	40	88	40	90	43	88	34	82	22	55	18	56	9
1908	51	4	56	-3	75	21	80	24	89	30	91	36	92	46	95	43	95	28	84	24	68	17	59	7
1909	66	-11	60	-2	60	12	81	13	84	31	89	42	89	45	89	41	90	30	81	22	72	21	66	-6
1910	45	-1	48	-12	84	18	81	23	82	25	90	35	94	44	94	38	91	34	85	24	66	14	49	0
1911	56	-11	62	9	67	4	77	16	92	28	94	46	101	43	97	41	87	37	75	22	65	10	61	7
1912	44	-24	55	-16	68	6	78	23	86	36	88	31	90	51	89	41	93	30	82	26	68	18	58	8
1913	57	4	62	-2	74	1	83	20	86	25	96	32	95	42	96	45	93	28	81	24	73	12	56	7
Extremes	72	-24	65	-21	84	-5	92	12	97	25	98	31	101	40	99	37	98	28	92	19	73	6	66	-11

METEOROLOGY—TABLE XI. Concluded

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-SIX YEARS FOR THE STATE

Date	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	68	-15	68	-10	77	-6	92	19	91	23	102	34	97	42	102	35	92	26	80	22	80	17	62	1
1889	61	-8	70	-14	82	10	88	15	96	26	92	38	98	46	100	40	98	28	82	17	77	9	73	10
1890	75	1	73	5	69	-4	86	20	92	28	101	39	101	43	103	40	92	33	85	29	76	17	65	3
1891	65	3	80	-2	74	-5	95	15	93	25	98	40	95	41	101	39	99	36	93	20	76	0	66	9
1892	61	-27	74	-1	80	-6	90	14	99	28	101	47	103	40	99	45	96	34	89	20	76	8	70	-12
1893	63	-24	68	-14	87	-8	93	20	94	23	102	40	101	42	101	37	100	24	95	15	76	-2	72	-5
1894	66	-16	76	-15	91	3	97	16	98	31	102	29	105	36	104	36	103	27	90	15	79	4	70	-27
1895	62	-19	70	-24	86	-7	90	16	102	19	105	29	106	34	103	31	105	25	84	8	85	5	79	-13
1896	70	-14	78	-18	73	-7	103	15	99	36	98	33	102	39	102	35	100	25	85	17	79	7	67	-15
1897	71	-27	72	-9	82	5	92	11	91	25	102	31	113	44	101	38	105	25	97	20	76	8	71	-7
1898	71	-18	72	-20	84	5	87	10	92	29	99	39	105	38	100	40	102	33	96	20	76	2	67	-18
1899	66	-15	67	-39	76	0	94	6	96	28	102	36	105	41	104	39	107	26	94	20	79	18	69	-7
1900	67	-20	80	-20	70	-9	87	15	97	20	96	38	103	38	103	40	100	33	93	23	80	0	65	-2
1901	67	-10	60	-20	84	-8	91	18	90	26	103	30	109	48	101	42	98	29	88	20	79	10	73	-19
1902	63	-11	66	-17	82	-4	90	17	98	24	98	33	100	43	97	37	94	24	88	21	87	17	63	-11
1903	73	-13	69	-20	86	11	88	10	93	22	95	35	104	42	101	38	98	26	93	15	88	2	57	-11
1904	70	-30	75	-18	86	-1	81	7	95	27	98	37	99	41	97	38	99	23	92	15	75	0	69	-16
1905	65	-17	54	-22	85	-5	89	12	93	26	99	34	100	44	96	41	95	30	89	20	71	10	58	2
1906	79	-14	72	-23	74	-12	91	18	94	24	100	34	98	43	101	43	98	36	91	18	82	14	68	-15
1907	75	-23	66	-19	96	-2	86	10	89	24	96	36	98	37	96	40	93	29	88	19	71	11	69	2
1908	59	-8	66	-22	85	12	91	16	96	25	100	33	102	42	104	37	100	24	90	15	77	5	68	-2
1909	74	-17	70	-17	70	6	90	13	91	24	96	36	97	40	96	35	95	25	86	16	80	15	75	-20
1910	62	-24	68	-25	90	12	88	19	88	21	97	33	98	43	100	36	93	34	94	18	78	11	63	-10
1911	68	-19	76	-2	81	1	86	8	101	25	101	40	107	41	104	34	97	33	88	20	79	8	79	-3
1912	57	-37	68	-25	80	-3	89	15	91	31	93	28	101	42	95	40	99	29	93	23	82	8	74	-5
1913	70	3	77	-15	80	-8	90	18	95	23	105	29	103	40	102	39	102	26	96	18	78	2	65	-3
Extremes	79	-37	80	-39	96	-12	103	6	102	19	105	28	113	34	104	31	107	23	97	8	88	-2	79	-27

TABLE XII: MONTHLY RAINFALL AT DISTRICT TEST-FARMS

Rainfall—inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
							Strongsville							
1897	.91	1.62	3.29	3.88	5.99	1.88	5.56	3.25	1.13	.87	7.02	1.92	37.32	1897
1898	5.47	3.75	4.82	2.37	3.43	5.60	4.25	5.69	2.72	5.59	3.25	7.39	54.33	1898
1899	4.35	2.32	5.25	3.11	5.58	2.10	5.75	.61	3.14	2.86	1.55	6.36	42.98	1899
1900	3.22	5.53	3.01	2.22	1.85	1.36	4.73	2.49	3.56	2.22	4.91	1.94	37.04	1900
1901	2.73	2.20	4.35	4.76	5.14	3.32	3.15	7.46	5.51	.47	2.51	5.34	48.94	1901
1902	1.17	1.40	2.64	2.91	4.29	9.34	7.39	4.52	5.58	2.73	2.35	3.34	47.68	1902
1903	2.37	2.97	3.18	6.68	1.45	3.78	6.49	8.72	1.88	3.09	2.70	2.62	45.93	1903
1904	6.51	3.59	4.68	3.47	6.07	1.45	5.80	3.48	2.73	1.20	.50	3.87	43.35	1904
1905	2.48	2.78	3.24	3.97	4.38	2.18	5.04	4.11	3.50	2.95	2.92	1.66	39.16	1905
1906	2.03	2.06	....	1.93	1.01	4.67	2.72	4.30	6.70	....	4.77	5.12	.....	1906
1907	5.21	1.20	....	....	....	....	....	....	....	....	....	....	.....	1907
1908	....	....	....	....	2.82	2.78	3.70	3.10	1.00	1.60	1.08	1.90	.....	1908
1909	2.48	2.56	....	3.49	4.13	3.20	4.40	3.60	2.71	2.60	2.80	1.30	.....	1909
1910	4.80	2.21	1.10	....	3.05	2.50	1.00	1.37	4.85	3.90	3.98	2.99	.....	1910
1911	....	1.16	1.85	3.03	1.95	1.80	.80	3.28	5.33	3.85	....	1.51	.....	1911
1912	1.38	1.49	2.91	5.12	3.62	1.80	6.88	4.74	4.34	2.40	.20	1.89	36.77	1912
1913	4.50	1.45	9.30	2.08	2.15	1.30	2.60	1.70	3.30	3.59	2.61	1.13	35.71	1913
Av.......	3.31	2.39	3.82	3.50	3.56	3.07	4.39	3.90	3.62	2.66	2.88	3.14	42.65	

TABLE XII: MONTHLY RAINFALL AT DISTRICT TEST-FARMS—Continued

Rainfall—inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
							Germantown							
1905	....	....	....	3.45	7.70	3.00	3.80	7.90	3.56	4.10	2.24	2.28	.....	1905
1906	2.92	1.07	6.93	1.88	1.34	2.88	6.24	7.46	2.30	1.65	3.80	4.32	42.79	1906
1907	7.22	.32	6.25	2.26	3.20	3.65	4.10	1.93	5.64	2.92	3.25	3.22	43.96	1907
1908	2.11	6.33	4.24	4.53	4.47	1.42	3.86	1.36	.35	.27	1.70	1.31	31.95	1908
1909	3.41	7.67	2.07	5.58	6.98	5.93	4.50	3.34	.89	3.13	1.95	4.00	49.45	1909
1910	3.00	4.25	.10	1.87	5.08	1.58	3.95	1.11	3.96	7.60	.96	2.85	36.41	1910
1911	5.00	1.46	3.00	6.01	1.36	2.67	1.78	4.56	5.16	4.48	3.06	3.81	42.35	1911
1912	3.23	1.68	4.29	6.51	3.49	2.24	3.78	9.05	2.50	2.79	.72	3.30	43.58	1912
1913	8.40	2.05	7.32	5.25	2.62	2.40	3.49	2.23	2.33	2.56	4.80	.88	44.33	1913
Av.....	4.41	3.10	4.28	4.15	4.03	2.86	3.94	4.33	2.97	3.28	2.50	2.89	41.85	
							Carpenter							
1903	....	....	....	3.75	5.69	5.07	4.23	1.02	1.02	2.60	2.73	3.28	.....	1903
1904	3.74	2.89	5.07	3.03	2.69	3.16	3.79	2.71	2.08	1.10	.18	3.40	33.84	1904
1905	1.02	1.35	4.07	2.70	7.02	5.11	3.77	4.11	1.02	5.20	2.45	3.51	41.33	1905
1906	3.58	1.85	3.82	1.43	1.40	6.39	1.40	2.92	3.24	2.58	3.50	3.50	35.61	1906
1907	8.94	2.28	6.13	3.57	3.47	4.49	4.84	4.10	2.94	2.38	2.14	1.72	47.00	1907
1908	1.37	4.31	7.80	5.15	4.38	2.92	3.74	3.50	.48	.85	1.37	2.13	37.98	1908
1909	3.05	5.72	2.77	4.10	4.29	7.63	4.18	2.18	.86	2.12	.90	2.05	39.85	1909
1910	6.40	4.70	.20	3.23	2.91	2.35	3.40	1.74	.99	1.68	1.42	2.80	31.82	1910
1911	5.56	3.08	2.26	3.90	2.06	6.14	1.19	4.69	5.18	3.68	2.20	4.01	43.95	1911
1912	1.48	2.44	3.39	4.04	2.90	2.92	5.46	2.56	2.51	1.80	.38	2.09	31.97	1912
1913	6.78	1.98	1.71	2.74	4.28	2.29	2.64	2.38	2.07	2.89	2.34	2.36	34.41	1913
Av.....	4.19	3.06	3.72	3.42	3.73	4.41	3.51	2.90	2.04	2.44	1.78	2.80	37.78	

THIRTY-THIRD ANNUAL REPORT

FOR 1913-1914

PRESS BULLETINS—INDEX

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JUNE, 1914

BULLETIN 278

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

Thirty-Third Annual Report

OF THE

Ohio Agricultural Experiment Station

For the Year ending June 30, 1914

Published by order of the State Legislature

WOOSTER, OHIO
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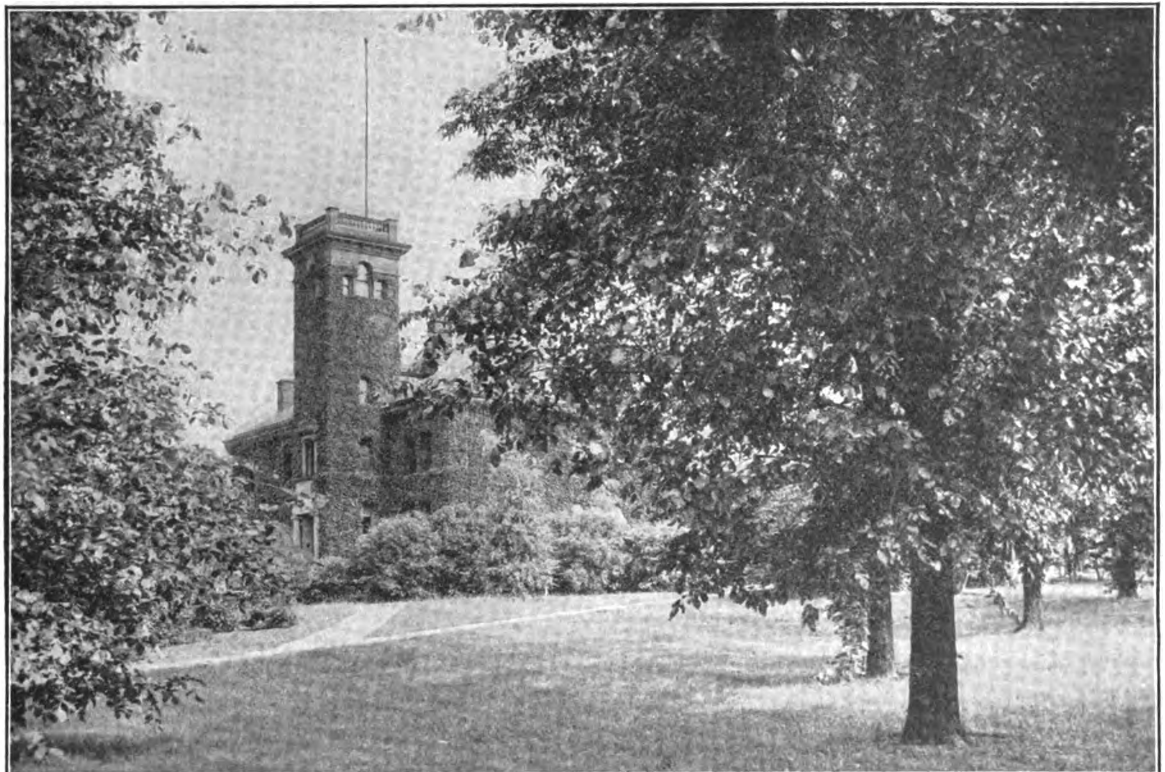
1914



Administration Building, Ohio Agricultural Experiment Station

ANNOUNCEMENT

The Ohio Agricultural Experiment Station is organized under an act of the General Assembly of Ohio, passed April 17, 1882, and supplemented by an act of Congress, approved March 2, 1887.

WHAT THE STATION CAN DO

The Station offers its advice and assistance to the farmers of Ohio along the following lines:

The maintenance of soil fertility, including the rotation of crops and the selection and use of manures and fertilizing materials.

The selection of varieties of grains, grasses and forage crops and methods of culture.

The selection of varieties of fruits and vegetables and the management of orchards.

The examination of seeds that are suspected of being unsound or adulterated; the identification of grasses, weeds and other plants; the prevention of fungous diseases of plants.

The identification of insects and the control of such as are injurious.

The feeding of animals, including calculation of rations and use of various feeding stuffs.

The planting and care of forest trees and the management of farm woodlots.

WHAT THE STATION CANNOT DO

For advice and assistance along the following lines, application should be made to the OHIO AGRICULTURAL COMMISSION, Columbus, not to the Experiment Station.

The analysis of commercial fertilizers, of lime or limestone for agricultural purposes, and of feeding stuffs.

The treatment of contagious diseases of animals.

The inspection of orchards and nurseries for the control of San Jose scale.

The examination of foods, drugs, and dairy products suspected of being adulterated.

The Station is not prepared to analyze drinking water; requests for such analysis should be addressed to the SECRETARY OF THE STATE BOARD OF HEALTH, Columbus.

Visitors to the Station or its various test farms are welcome at all times during business hours. Persons or parties who contemplate such visits and who desire special attention are requested to write in advance, giving date of proposed visit and probable number of party.

Any citizen of Ohio has the right to apply to the Station for such assistance as it can give, and all such requests will receive prompt attention.

The Bulletins of this Station are sent free to all residents of the State who request them.

Address all communications to

EXPERIMENT STATION,

Wooster, Ohio.

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[1]With leave of absence. [2]In cooperation with Weather Service, U. S. Department of Agriculture.
[3]In cooperation with Bureau of Plant Industry, U. S. Department of Agriculture.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 279 JULY, 1914

THE MAINTENANCE OF FERTILITY

LIMING THE LAND

BY C. E. THORNE

In Bulletin 159 of this Station is reported the plan and earlier results of an experiment in the use of lime on crops grown in a 5-year rotation of corn, oats, wheat, clover and timothy.

There are five tracts of land in this experiment, named A, B, C, D, and E, so that each crop may be grown every season. Each tract is subdivided into 30 plots, containing one-tenth acre each, the plots being separated by paths 2 feet wide. The diagram shows the arrangement of plots and scheme of fertilizing, the fertilizers being applied to the cereal crops only; the clover and timothy, which are sown together, following without any further treatment. Every third plot, beginning with No. 1, is left continuously without fertilizer or manure. A tile drain is laid 30 inches deep under alternate paths, thus spacing the drains 36 feet apart.

The experiment is located on land which had been subjected to an exhaustive system of husbandry, the soil being a light, silty clay, overlying the shaly sandstones of the Upper Waverly.

From the beginning of the test, in 1894, there was difficulty in securing a satisfactory stand of clover, and this difficulty increased from year to year. In 1900 a dressing of one ton per acre of caustic lime was applied to the west half of Section E, as it was being prepared for corn, the lime being applied after plowing and harrowed in. The lime was applied to all the land, fertilized and unfertilized alike. This treatment was repeated on the west half of each of the succeeding sections as they came under corn until Section E was reached again, in 1905, when the liming was transferred to the east half, and continued on that half for three years. By this time it was demonstrated that the differences which were being shown

in the crops were due to the liming and not to natural variations in soil, and the liming was returned to the west half, and has since been continued on that half only. Because of this shifting of the liming, sections E, B and A have had one liming on the east end, which has reduced the contrast between the two ends, so that the results which follow do not show the full effect of the treatment.

After going once over the 5 sections with quicklime, ground limestone was substituted and has been used at the rate of one ton per acre, thus carrying only about half as much calcium and magnesium as was used at first. This reduction in quantity was made because it was apparent that the full effect of the first liming had not been exhausted by the five crops of the rotation; but the later crops are indicating a need for more lime and the quantity of limestone was increased to 2 tons for the corn crop of 1914.

In 1903 the corn was so injured by white grub that no trustworthy contrast could be made between the two halves of the section (C) and in 1912 the crop was again so injured by the same pest (on Section A) that the crop was plowed under.

EFFECT OF LIME ON CORN

In Table I is given the average yield of the 12 crops of corn harvested during the period 1900-1913, the data being arranged in groups according to the principal treatments, and omitting the plots which have received only partial fertilizing, and No. 30, the plan of which was changed after several years of low fertilizing.

Table I shows that the liming has added materially to the yield of corn under every treatment and on the untreated land. The lowest gain for lime is found on the plot receiving phosphorus in basic slag, and the highest gains are on the plots receiving nitrogen in oilmeal, dried blood and sulphate of ammonia. Without lime, these carriers of nitrogen produce less total corn than does nitrate of soda, but with lime they surpass the nitrate in yield. Wherever nitrate of soda is used in the fertilizer it increases the total yield but reduces the demand for lime; the larger the applications of nitrate the greater this reduction, but no practicable application of nitrate is able to obviate the necessity for liming.

The last two columns of the table show the increase produced by the fertilizers in addition to that caused by the liming. In calculating this increase it is assumed that the variations in the yield of neighboring plots are likely to be progressive. That is, that if Plots 1 and 4, unfertilized, yield 30 and 33 bushels respectively, the probable unaided yields of Plots 2 and 3 would have been 31 and 32 bushels.

TABLE I: Average yield of CORN and increase from lime and from fertilizers for 12 years, 1900-1913, (excluding 1903 and 1912)
Bushels per acre

Treatment (Fertilizers per acre for complete rotation)	Plot No.	Yield per acre		Gain for lime	Increase from fertilizers	
		Unlimed	Limed		Unlimed	Limed
I: Without nitrogen:						
Phosphorus, 20 lbs. in acid phosphate	2	36.13	43.64	7.51	9.85	9.08
Phosphorus, 20 lbs.; potassium, 108 lbs. in muriate of potash	8	43.86	51.68	7.82	17.14	17.82
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	48.85	56.29	7.42	24.22	23.60
" " linseed oilmeal	21	45.89	57.56	11.67	22.13	23.06
" " dried blood	23	47.16	57.19	10.03	22.76	22.73
" " sulphate of ammonia	24	45.80	57.68	11.88	20.08	22.52
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs.; and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	49.06	55.73	6.67	22.94	22.64
" " bonemeal	26	45.53	52.99	7.46	17.85	17.01
" " dissolved boneblack	27	48.60	54.77	6.17	20.29	18.68
" " basic slag	29	48.71	52.07	3.36	19.76	15.88
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	50.12	55.45	5.33	24.39	22.24
V: Yard manure, estimated to carry nitrogen 144 lbs.; phosphorus 48 lbs.; and potassium, 112 lbs.	18	56.02	62.71	6.69	31.14	28.37
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs.	20	56.02	51.93	8.83	18.65	16.68
Average unfertilized yield		25.96	34.21	8.25	.....	.....

The average yield of all the unfertilized plots is given as a comparison between the yields of different seasons, but it is never used in the calculation of increase. The increases shown in the table and those following, therefore, are those calculated from the yields of neighboring unfertilized or check plots. In the case of the unlimed land these plots have had neither lime nor fertilizer, while on the limed land the check plots have had lime but no fertilizer. In the case of the low-nitrogen treatment the fertilizers have usually produced as much increase of corn on the limed as on the unlimed land, but on the high-nitrogen plots, including the manured plots, the increase from the fertilizers is greater on the unlimed land, thus indicating that a part of the effect of liming has been the favoring of nitrification.

EFFECT OF LIME ON OATS

Table II shows the average yields of 10 crops of oats harvested in this experiment, the crops of 1902, 1903 and 1904 not having been separately harvested. The table indicates a much smaller effect on the oats crop than that found in the corn crop. It is possible that a part of this difference may be due to the fact that the corn stubble is always plowed for oats in this test, thus turning down the lime that had been applied on the surface for the corn. With the oats, as with the corn, the greatest increase from the liming is found in the low-nitrogen plots, the one to which the nitrogen is carried in sulphate of ammonia leading. On several of the high-nitrogen plots there is an actual loss of crop after liming. It will be observed that the manured plots do not receive manure on the oats crop, that crop following as a gleaner after corn.

EFFECT OF LIME ON WHEAT

Table III shows that the wheat crop is responding regularly to the liming, the only treatment which fails to show a larger yield on the limed than on the unlimed land being the one in which the phosphorus is carried in basic slag. The largest increase from lime is found on the plot receiving its nitrogen in sulphate of ammonia. Without lime this plot falls 2½ bushels below the one dressed with nitrate of soda, but with lime the two carriers of nitrogen give exactly the same yield. On the no-nitrogen and low-nitrogen plots, excepting No. 21, the increase from fertilizers is greater on the limed than on the unlimed land.

EFFECT OF LIME ON CLOVER

The oat-stubble is plowed for wheat, thus bringing the lime near the surface again, besides mixing it very thoroughly through the soil, and the clover responds to the liming with a larger rate of

TABLE II: Average yield of OATS and increase from lime and from fertilizers for the 10 years, 1901, and 1905 to 1913, inclusive.
Bushels per acre

Treatment (Fertilizers per acre for complete rotation)	Plot No.	Yield per acre: Unlimed	Yield per acre: Limed	Gain or loss (—) for lime	Increase from fertilizers: Unlimed	Increase from fertilizers: Limed
I: Without nitrogen:						
Phosphorus, 20 lbs. in acid phosphate	2	39.20	42.07	2.87	10.74	11.00
Phosphorus, 20 lbs., potassium, 108 lbs. in muriate of potash	8	42.57	46.07	3.50	15.73	16.27
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	51.18	50.55	—.63	23.55	21.19
" " linseed oilmeal	21	47.09	49.86	2.77	20.16	19.79
" " dried blood	23	47.61	48.47	.	20.86	18.41
" " sulphate of ammonia	24	46.23	50.04	3.81	19.19	19.50
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs., and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	49.61	47.61	−2.00	22.35	18.06
" " bonemeal	26	45.06	45.20	.14	16.99	14.23
" " dissolved boneblack	27	47.59	46.40	—1.19	18.77	15.50
" " basic slag	29	45.66	44.54	—1.12	16.10	13.70
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs, and potassium, 108 lbs.	12	47.87	48.80	.93	20.60	19.00
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus 48 lbs., and potassium, 112 lbs.	18	42.08	43.48	1.40	14.32	13.27
Yard manure, estimated to carry nitrogen 72 lbs. phosphorus, 24 lbs., and potassium, 56 lbs.	20	36.04	39.72	3.68	8.63	9.15
Average unfertilized yield		27.51	30.23	2.72	....	.....

increase than is given by any other crop. Not only does the clover show a great direct increase from the liming, but in every instance, excepting only the plot to which phosphorus is carried in basic slag, the residual increase from the fertilizers which have been applied to the previous crops is materially greater on the limed than on the unlimed land.

The effect of nitrate of soda is strikingly brought out in the comparison of Plots 17, 21, 23 and 24, and of this group of plots with those receiving the larger quantity of nitrate. On the unlimed land the increase from the complete fertilizers used on Plots 21, 23 and 24 is no greater in the average than on Plot 8, which receives no nitrogen, while that on Plot 17 is materially greater. The behavior of the clover crop is very different from that of the cereal crops, for although in these crops also nitrate of soda has been more effective than the other carriers of nitrogen, the difference has been less conspicuous than with the clover, notwithstanding the fact that nitrate of soda is supposed to be relatively more evanescent in its effect, as compared with nitrogen in organic materials. Considering all the evidence the conclusion seems to be warranted that a part of the superior effect of nitrate of soda on this acid soil has been due tc the sodium contained, that element having been liberated when the salt was being decomposed to give up its nitrogen to the crops which preceded the clover.

That the increase in the quantity of nitrate of soda, as used on Plot 12, has not produced a greater effect, may be explained on the assumption that the formula used on this plot has not carried enough phosphorus or potassium, one or both, to properly balance the nitrogen given, and hence a considerable part of the nitrate has been wasted.

On the third group of plots the proportion of clover in the stand has been conspicuously greater on the unlimed land to which the phosphorus is carried in bonemeal or basic slag than under other treatments, and this has been especially the case on the manured land. The manured plots have also grown more timothy and fewer weeds during the season immediately after seeding than the fertilized land. The gain for lime, moreover, has been relatively smaller on the manured than on fertilized land. These points are explained by the absence of sulphuric acid in the manure and the bonemeal and basic slag mixture, and by the considerable amount of lime carried in the manure.

But neither nitrate of soda nor bonemeal nor basic slag nor any practicable combination of these materials, will furnish sufficient alkali to neutralize this acid soil, unless used in such quantity that the cost will be prohibitive.

TABLE III: Average yield of WHEAT and increase from lime and from fertilizers for the 8 years, 1906-1913.
Bushels per acre.

Treatment (Fertilizers per acre for complete rotation)	Plot No.	Yield per acre		Gain or loss (—) for lime	Increase from fertilizers	
		Unlimed	Limed		Unlimed	Limed
I: Without nitrogen:						
Phosphorus, 20 lbs. in acid phosphate	2	20.90	24.19	3.29	7.47	8.54
Phosphorus 20 lbs., potassium, 108 lbs. in muriate of potash	8	21.67	24.29	2.62	8.08	9.05
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	25.89	28.80	2.91	13.88	14.61
" " linseed oilmeal	21	24.81	26.75	1.94	12.88	11.73
" " dried blood	23	23.07	26.92	3.85	11.26	12.06
" " sulphate of ammonia	24	23.38	28.80	5.42	11.35	13.90
III: Nitrogen, 76 lbs., in nitrate of soda, with phosphorus, 20 lbs., and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	30.70	30.82	.12	17.44	15.71
" " bonemeal	26	26.18	27.23	1.05	14.06	12.40
" " dissolved boneblack	27	26.61	28.68	2.07	14.64	13.96
" " basic slag	29	27.87	26.46	—1.41	16.04	11.85
IV: Nitrogen, 114 lbs, in nitrate of sod with phosphorus, 20 lbs. and potassium, 108 lbs.	12	29.60	32.89	3.29	16.73	17.65
V: Yard manure, estimated to carry nitrogen 114 lbs., phosphorus 48 lbs., and potassium, 112 lbs.	18	28.40	31.42	3.02	16.09	16.60
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs.	20	23.23	26.02	2.79	10.96	10.79
Average unfertilized yield		12.64	15.01	2.37	.....	....

TABLE IV: Average yield of CLOVER HAY and increase from lime and from fertilizers for 11 years, 1903-1913
Pounds per acre

Treatment (Fertilizers per acre for complete rotation, all applied for corn, oats and wheat)	Plot No.	Yield per acre		Gain for lime	Increase from fertilizers	
		Unlimed	Limed		Unlimed	Limed
I: Without nitrogen:						
Phosphorus, 20 lbs. in acid phosphate	2	1,554	2,250	696	461	700
Phosphorus, 20 lbs., potassium, 108 lbs. in muriate of potash	8	2,286	3,476	1,190	883	1,439
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	2,596	3,842	1,246	1,287	1,968
" " linseed oilmeal	21	2 256	3,409	1,153	963	1,589
" " dried blood	23	2,123	3,515	1,392	793	1,708
" " sulphate of ammonia	24	2,256	3,736	1,480	859	1,842
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus 20 lbs., and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	2,796	3,631	835	1,438	1,718
" " bonemeal	26	3,135	3,981	846	1,654	1,978
" " dissolved boneblack	27	2,636	3,524	888	1,137	1,497
" " basic slag	29	3,072	3,579	507	1,554	1,530
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	2,853	3,765	912	1,481	1,845
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus 48 lbs. and potassium, 112 lbs.	18	3,582	4,708	1,126	2 253	2,761
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs. and potassium, 56 lbs.	20	2,517	3,312	795	1,195	1,392
Average unfertilized yield		1,409	1,983	574	.....	.....

TABLE V: Average yield of TIMOTHY HAY and increase from lime and from fertilizers for 7 years, 1906 to 1913 (excluding 1909)
Pounds per acre

Treatment (Fertilizers per acre for complete rotation, all applied on corn, oats and wheat)	Plot No.	Yield per acre		Gain for lime	Increase from fertilizers	
		Unlimed	Limed		Unlimed	Limed
I: Without nitrogen:						
Phosphorus 20 lbs. in acid phosphate	2	2,992	3,934	942	292	803
Phosphorus, 20 lbs., potassium, 108 lbs. in muriate of potash	8	2,982	4,008	1,026	546	819
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	3,197	4,635	1,438	839	1,456
" " linseed oilmeal	21	3,068	4,416	1,348	717	1,234
" " dried blood	23	2,987	4,388	1,401	548	1,185
" " sulphate of ammonia	24	2,923	4,617	1,694	365	1,261
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs, and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	3,507	4,389	882	1,081	1,273
" " bonemeal	26	3,436	4,876	1,442	744	1,352
" " dissolved boneblack	27	3,184	4,607	1,423	480	1,068
" " basic slag	29	3,837	4,567	730	1,120	1,014
IV: Nitrogen, 114 lbs., in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	3,517	4,434	917	1,078	1,391
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus, 48 lbs, and potassium, 112 lbs.	18	4,470	5,742	1,272	2,083	2,430
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs	20	3,627	4,841	1,214	1,244	1,527
Average unfertilized yield		2,512	3,225	713	.....	.....

EFFECT OF LIME ON TIMOTHY

The results on the timothy crop are given in Table V. On the unlimed land the timothy crop shows the same neglect of organic and ammonia nitrogen on Plots 21, 23 and 24, as compared with Plot 8, as that shown by the clover, but shows a somewhat greater response than clover to these carriers of nitrogen after lime has been added. The increase of nitrogen in nitrate of soda, in Group III, accompanied as it has been by a reduction of phosphorus, has not produced a further increase in yield on the limed land.

The total gain for lime in the timothy crop has been greater, and the percentage gain nearly as great as in the clover, and in both it has been much greater than in the oats or wheat, notwithstanding the fact that these crops have been grown at an earlier period after the liming than the clover and timothy.

THE FINANCIAL OUTCOME

Table VI gives the total value of all the crops for each rotation for the limed and unlimed land, the value of the gain for lime and that of the increase from the fertilizers, rating corn at 40 cents per bushel, oats at 30 cents and wheat at 80 cents, with stover at $3.00 per ton, straw at $2.00 and hay at $8.00.

As shown by this table, on the unlimed land the total value of the 5 crops of the rotation has amounted to $49.40 for the average of the unfertilized land and to $67.80 for the land receiving acid phosphate only, but the value of the increase on this land over the neighboring unfertilized land has been $17.81, because of the fact that the increase is calculated, not on the average of all the unfertilized plots, but on those nearest the treatment under consideration.

When the land has had lime in addition to the phosphate, the yield has run to $81.80 in value, or $14.00 more than that of the unlimed land, while the increase from the fertilizer has amounted to $21.52, making a total gain for lime and fertilizer of $35.52.

The addition of muriate of potash to the fertilizer has increased the total value of the crops to $76.28 on the unlimed and to $92.33 on the limed land, the gain for the fertilizer being $26.38 on the unlimed, and $30.95 on the limed land; the gain for lime alone being $16.05 and that for lime and fertilizer amounting to $47.00

When nitrogen in sulphate of ammonia has been added to this combination of phosphorus and potassium, the phosphorus being increased by 50 percent, the value of the produce has been $80.04 on the unlimed land and $104.15 on the limed land. Comparing with the neighboring unfertilized land, we find that this combination has increased the yield by $31.15 on the unlimed, and by

TABLE VI: Average value of crops for one rotation and value of increase for lime and for fertilizers.*

Treatment (Fertilizers per acre for each rotation)	Plot No.	Value per acre of total crops		Value of gain for lime	Value of increase from fertilizers	
		Unlimed	Limed		Unlimed	Limed
I: With nitrogen:						
Phosphorus, 20 lbs., in acid phosphate	2	$67.80	$81.80	$14.00	$17.80	$21.52
Phosphorus 20 lbs., potassium, 108 lbs. in muriate of potash	8	76.28	92.33	16.05	26.38	30.95
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.						
Nitrogen in nitrate of soda	17	87.76	104.49	16.73	40.96	45.47
" " linseed oilmeal	21	82.20	99.82	17.62	35.61	39.04
" " dried blood	23	80.40	99.71	19.31	33.18	39.04
" " sulphate of ammonia	24	80.04	104.15	24.10	31.15	42.02
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs., and potassium, 108 lbs.						
Phosphorus in acid phosphate	11	93.83	103.16	9.33	44.52	43.16
" " bonemeal	26	87.60	100.90	13.30	36.52	37.31
" " dissolved boneblack	27	87.28	100.81	13.53	35.70	37.24
" " basic slag	29	92.36	96.59	4.23	40.25	32.05
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	92.87	106.13	13.26	43.95	46.17
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus 48 lbs., and potassium, 112 lbs.	18	99.08	115.05	15.97	51.09	53.56
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs.	20	78.58	94.49	15.91	30.96	32.12
Average unfertilized yield		49.40	61.40	12.00	.....	.....

*Valuations: Corn, 40 cents per bu.; oats, 30 cents; wheat, 80 cents; hay, $8.00 per ton; stover $3.00 and straw $2.00.

$42.02 on the limed land. In other words, the fertilizers alone have increased the yield by $31.15 and the fertilizers and lime have increased it by $66.12.

When nitrate of soda has been substituted for sulphate of ammonia as the carrier of nitrogen the increase from the fertilizers has been nearly $10.00 greater on the unlimed land, and $3.45 greater on the limed land than that produced by the combination carrying its nitrogen in sulphate of ammonia.

The combined increase from lime and fertilizers carrying nitrate of soda has averaged $62.19, and that from lime and fertilizers carrying sulphate of ammonia has averaged $66.12; the total yields, however, have had the same value, within a few cents, indicating that the higher increase found after sulphate of ammonia in this case has been due to a lower rate of yield of the unfertilized land.

Where the nitrogen has been given in organic form, in linseed oilmeal or dried blood, the increase on the unlimed land has been a little greater than that from sulphate of ammonia, but on the limed land the sulphate of ammonia has produced the greater increase.

In the case of carriers of phosphorus, basic slag seems to have been a little less effective than acid phosphate on unlimed land, while on the limed land acid phosphate has produced a decidedly greater effect than the slag, the difference amounting to ten dollars for each rotation. In comparing these phosphates the total phosphorus in basic slag has been set against the available phosphorus in acid phosphate. Even on this basis the cost of a pound of phosphorus is usually a little greater in basic slag than in acid phosphate.

The value of increase from fertilizers is $3.66 greater on the unlimed half of Plot 11, receiving for each rotation 480 pounds of nitrate of soda and 320 pounds of acid phosphate, than on Plot 17, receiving 240 pounds of nitrate of soda and 480 pounds of acid phosphate, but the fertilizers for Plot 11 have cost $5.90 more than for Plot 17. On the limed half the increase on plot 17 is greater than on Plot 11. The still larger application of nitrate of soda, on Plot 12, fails to meet a corresponding response in increase of crop. Evidently, so far as this soil and these crops are concerned, the ratio of nitrogen to phosphorus has been more effective on Plot 17 than on either Plot 11 or Plot 12.

In Table VII is shown the cost of treatment and the net gain per acre for the limed and unlimed land for each rotation, the cost of liming being estimated at five dollars per acre, and the nitrogen and phosphorus in other carriers being computed at the same cost as in nitrate of soda and acid phosphate, except in the case of manure,

TABLE VII: Cost of treatment and net gain per acre

Treatment	Plot No.	Cost of treatment*		Net gain per acre	
		Unlimed	Limed	Unlimed	Limed
I: Without nitrogen:					
Phosphorus, 20 lbs. in acid phosphate	2	$ 2.60	$ 7.60	$15.20	$24.20
Phosphorus, 20 lbs., potassium, 108 lbs. in muriate of potash	8	9.10	14.10	17.28	28.33
II: Nitrogen, 38 lbs., with phosphorus, 30 lbs., and potassium, 108 lbs.					
Nitrogen in nitrate of soda	17	17.60	22.60	23.46	35.09
" " linseed oilmeal	21	17.60	22.60	18.01	30.63
" " dried blood	23	17.60	22.60	15.58	29.89
" " sulphate of ammonia	24	17.60	22.60	13.55	32.65
III: Nitrogen, 76 lbs. in nitrate of soda, with phosphorus, 20 lbs., and potassium, 108 lbs.					
Phosphorus in acid phosphate	11	23.50	28.50	21.02	25.35
" " bonemeal	26	23.50	28.50	13.02	21.32
" " dissolved boneblack	27	23.50	28.50	12.20	20.73
" " basic slag	29	23.50	28.50	16.75	15.98
IV: Nitrogen, 114 lbs. in nitrate of soda, with phosphorus 20 lbs. and potassium, 108 lbs.	12	30.70	35.70	13.25	21.51
V: Yard manure, estimated to carry nitrogen 144 lbs., phosphorus 48 lbs., and potassium, 112 lbs	18	32.00	37.00	19.09	35.06
Yard manure, estimated to carry nitrogen 72 lbs., phosphorus, 24 lbs., and potassium, 56 lbs.	20	16.00	21.00	14.96	25.87

*Valuations: In fertilizers, phosphorus, 13 cents per lb.; potassium, 6 cents; nitrogen, 19 cents. In manure, nitrogen is computed at 15 cents and phosphorus at 7½ cents—the approximate cost of these elements in tankage and fine bone as estimated in the Official Report on Commercial Fertilizers for 1913, of the Agricultural Commission of Ohio.

where the nitrogen is estimated at 15 cents and the phosphorus at 7½ cents per pound, following the valuation for these elements in tankage and fine bone in the Official Report on Commercial Fertilizers for 1913 of the Agricultural Commission of Ohio. At these valuations a ton of yard manure would be worth two dollars, and the outcome shows that, when supplemented by liming, the yard manure has produced a very profitable increase, although the gain per pound of fertilizing elements contained is not equal to that from the best proportioned chemical application. Other experiments* have shown that before we can expect to realize the full effect of manure we must re-enforce it with some carrier of phosphorus, and must avoid the wastes which occur in the ordinary barnyard.

CONCLUSIONS

The experiments reported in this bulletin show that on soils deficient in lime it is as necessary to make good this deficiency as it may be to make good that of nitrogen, phosphorus or potassium. They show, moreover, that lime does not take the place of other fertilizing elements, but only accomplishes its full effect when used in connection with liberal manuring or fertilizing.

WHAT IS LIME?†

Everyone who has handled a lump of quicklime has noticed that it is much lighter in weight than an unburnt limestone of equal bulk. This means that one of the materials of which the original stone was composed has been driven off from the stone by the burning, and has escaped as an invisible gas into the atmosphere. This gas is carbon di-oxide (di meaning two) the "carbonic acid gas" of the older chemistry. It is the same gas which is breathed out of the lungs, and if we pass our breath through a tube into the bottom of a tumbler of limewater a white cloud will be formed by the union of the carbon di-oxide of the breath with the lime dissolved in the water, thus reversing the results attained by burning; for the white cloud in the tumbler and the limestone in the quarry are both the same substance, namely; carbonate of lime.

If we first thoroughly dry a pure limestone and then burn it, we shall find that it has lost about 44 percent of its original dry weight. That is, 100 pounds of pure, dry limestone, or carbonate of lime, will produce about 56 pounds of lime. But what is lime?

*See Bulletin 183 of this Station.

†From the Official Report for 1913 on Commercial Fertilizers and Agricultural Lime of the Agricultural Commission of Ohio.

CALCIUM

The chemist is able to separate the burnt lime into two constituents, one of which again is the oxygen gas which constitutes about one-fifth of the air we breathe, while the other is a brilliant, light yellow metal called calcium, which rapidly tarnishes when exposed to moist air by recombining with oxygen and returning to lime. This elementary metal, calcium, is the essential constituent to which lime owes its peculiar properties. Oxygen and carbonic acid may be found in thousands of other combinations which have none of the characteristics of lime and perform none of its functions. We use lime, therefore, simply as a convenient carrier of calcium.

HYDRATED LIME

If we expose a lump of freshly burnt lime to ordinary moist air, in the course of a few days, or weeks, depending largely upon the amount of moisture in the air, it will be found to have crumbled into a fine powder. In other words, it is air slaked. We may accomplish this result much more quickly by pouring water on the lump of lime, when it will fall to powder before our eyes, and with the evolution of considerable heat, thus showing that a chemical operation has taken place, in which the water has become chemically combined with the lime; for, unless excess of water has been used this powder will be just as dry to our senses as the original quicklime. This combination of lime with water is called hydrated lime, and if we weigh the powder resulting from either air slaking or water slaking we will find it to be about one-third heavier than the original quicklime from which it was produced, this additional weight being due to chemically combined water.

ATOMIC WEIGHTS

Chemists have found that elementary substances, such as calcium, carbon, oxygen and hydrogen always combine with each other in certain fixed weights, or multiples of such weights, which are called atomic weights, or combining weights; and hydrogen, which is the gas which causes balloons to rise, and is the lightest of known elements, is taken as the unit of weight. (The reason balloons rise is that hydrogen is lighter than air, not that hydrogen has no weight of itself; just as wood floats upon water because it is lighter than the water. If hydrogen be placed in a vacuum it will fall, instead of rising, just as wood falls in air.)

Measured by hydrogen as unity, the other elements which enter into the composition of lime in its various forms have the following atomic weights:

Calcium (Ca)	40
Oxygen (O)	16
Carbon (C)	12
Hydrogen (H)	1

CHEMICAL SYMBOLS

In order to save space and time each element is given a symbol to designate it, these symbols being usually the first one or two letters of the name of the element, and the symbols of the elements under consideration are as given above in parentheses. In designating chemical compounds these symbols are so used as to show not only the elements contained but the proportion of each element in the compound: Thus water, which is a chemical combination of two combining weights of hydrogen with one combining weight of oxygen, has the symbol H_2O, which means that in 18 pounds of water 2 pounds are hydrogen and 16 pounds are oxygen; but 2 is approximately 11 percent of 18, and 16 is about 89 percent of 18, so we say that water is 11 percent hydrogen and 89 percent oxygen.

The symbol for lime is CaO, meaning that 40 pounds of calcium are combined with 16 pounds of oxygen in every total of 56 pounds; or 71 percent of calcium and 29 percent of oxyge

The symbol for carbon di-oxide is CO_2, meaning that one combining weight of carbon is united with two combining weights of oxygen, or 12 parts by weight of carbon with 32 parts by weight of oxygen, so that this gas is a little more than 27 percent carbon and a little less than 73 percent oxygen.

In carbonate of lime we have three elements to consider: calcium, carbon and oxygen, and the symbol of this compound is CaO, CO_2 or $CaCO_3$, so that in a given weight of pure limestone we would have for every 40 pounds of calcium 12 pounds of carbon and 48 pounds of oxygen. The sum of these weights is just 100, so that 100 pounds of carbonate of lime contains 40 percent calcium, 12 percent carbon and 48 percent oxygen.

Hydrated lime has the symbol CaO, H_2O or CaH_2O_2, so that in a given weight of hydrated lime the elements would have the ratio 40:2:32, or 54 percent calcium, 2.7 percent hydrogen and 43.3 percent oxygen.

RELATIVE VALUE OF CALCIUM CARRIERS

Now let us see how much actual calcium we shall find in a ton of each of the different carriers mentioned:

Carrier	Symbol	Percentage composition				Pounds Calcium in one ton
		Ca.	O.	C.	H.	
Quicklime	CaO	71	29	..	...	1,420
Hydrated lime	CaO, H_2O	51	43.4	..	2.7	1,080
Carbonate of lime	CaO, CO_2	40	48	12	...	800

One tonof quicklime carries 1,420 pounds of calcium. To carry this quantity of calcium in hydrated lime would require as many hundred pounds of hydrated lime as 54, the quantity of calcium contained in 100 pounds of hydrated lime, is contained in 1,420 which is 26.3. It will therefore take 2,630 pounds of hydrated lime to carry as much calcium as is found in 2,000 pounds of quicklime. In the same way it is shown that 3,550 pounds, or nearly 2 tons, of carbonate of lime will be required to carry the calcium found in one ton of quicklime.

THE CARBONATES OF LIME

Three forms of carbonate of lime are on the market: one produced by grinding raw limestone, one found in the beds of marl sometimes found under muck beds, and one resulting from manufacturing processes in which the carbonate is produced by chemical processes analogous to that which is witnessed when we breathe through a tube into a glass of limewater. This process, by which the carbonate of lime is precipitated, to use the chemist's term, results in a much finer powder than can be produced by ordinary grinding, and hence a precipitated carbonate of lime may be more quickly available than ground limestone. In actual practice, however, the experiments made by the Ohio Experiment Station have shown no practical superiority of one form of lime over the other, provided the limestone has been so ground that 80 percent of it will pass through a sieve having 100 meshes to the linear inch, and provided also, of course, that the two materials are used on the basis of the actual calcium contained. As the outcome of these experiments the Experiment Station is using either one ton of quicklime or two tons of ground limestone per acre, which ever can be spread on the field in these quantities for the least money.

To illustrate this point, let us suppose that ground limestone and quicklime are offered at the same point of shipment at $1.25 per ton for the former and $5.00 for the latter. Let us assume that the freight will be $1.50 per ton, and the cost of hauling from the car and spreading $1.00 per ton. Our account will then stand as follows:

	Quicklime 1 ton	*Ground stone 2 tons*
Cost at point of shipment	$5.00	$2.50
Freight	1.50	3.00
Hauling and spreading	1.00	2.00
Total	$7.50	$7.50

ADULTERATED LIMES

A factor which is not taken into the above account is the greater discomfort in handling the quicklime than the ground stone. Moreover, sometimes, the so-called "agricultural lime" is suspected to

contain more or less unburnt stone, ashes, etc., accumulating at the bottom of the kiln, which are ground up together. Such lime, of course, would not be pure quicklime, and a very little adulteration of this sort would bring the value of the one ton of "agricultural lime" much below that of the two tons of limestone. On the other hand,. the ground stone is not always so finely ground as it ought to be to produce the best results, and it may sometimes be ground from rock containing sand or earth, although this probably is seldom the case, for when a product is worth only about a dollar per ton there is less inducement to adulterate it than when the price is higher.

MAGNESIA

Magnesia (MgO) is the oxide of the element magnesium, which is very similar in its characteristics to calcium, and the two are generally found associated in ordinary limestones. Magnesium has a somewhat greater effect than calcium in correcting acidity, 84 pounds of magnesium carbonate being equivalent in this respect to 100 pounds of calcium carbonate. Within certain limits the presence of magnesium in the limestone, therefore, is an advantage; but when used in excess magnesium may cause injury rather than benefit—which is also true of calcium, or any other good thing. The difference between magnesium and calcium in this respect is that it requires a smaller amount of the former than of the latter to cause injury. Such injury is more liable to follow the use of a magnesium lime, carrying magnesia in the caustic form, than when the carrier is in the carbonate form.

When the limestone carries nearly as much magnesium as calcium it is called a dolomite, and the use of quicklime made from such a stone might be questionable; when, however, the magnesia does not reach more than 25 to 30 percent in the lime there is but little danger of injury from it on ordinary Ohio soils, if applied at the usual rate of about a ton to the acre once in 4 or 5 years. There is but little danger from magnesia in the carbonate form.

THE CHIEF THING TO REMEMBER ABOUT LIME

The chief thing to remember about lime is that it is the natural calcium and magnesium carbonate which we find in limestone that does the work we want done in the soil, whether in feeding the plant or in neutralizing soil acidity, and that whatever be the carrier we may use, whether quicklime or hydrated lime, it will be quickly changed to the carbonate by the moisture and carbon di-oxide of the soil, and that the only reasons for using any other carrier than the natural carbonates are to secure the greatest fineness of division and to save freight and labor in handling.

WHEN TO USE LIME

Half the soils of Ohio—covering the region west of a line drawn from Sandusky through Columbus to the west line of Scioto county, excepting Williams and Fulton counties and adjoining portions of Henry and Defiance counties—lie over limestones. In this region there may be old fields in which the supply of lime in the plowed surface has become deficient, but as a rule the expense of a general application of lime should not be incurred until a preliminary test has been made. Such a test is best made by liming a narrow strip across a field and observing the effect on the clover crop. For such an experiment common hydrated or builder's lime may be used at the rate of 15 to 20 pounds per square rod or 2,000 to 3,000 pounds per acre

At the Experiment Station the best results have followed when the lime has been applied to the surface while the land was being prepared for corn, the cultivation of the corn crop and the subsequent plowings mixing the lime through the seed bed so thoroughly that when the clover crop has come along in its regular place in the rotation it has found the soil acidity thoroughly corrected.

THE LITMUS TEST

The litmus test is a simple chemical test for soil acidity, made by inserting a strip of blue litmus paper in moist soil and letting it stand for a few minutes. If the soil is acid, the paper will turn distinctly red. As the paper may sometimes be reddened by temporary conditions of acidity the actual application of lime as above described is much the better test. Litmus paper may be procured at most any drug store.

When lime is needed it should be applied in sufficient quantity to accomplish its work. At the Experiment Station the rule is to apply one ton of quicklime, 1⅓ ton of hydrated lime, or two tons of carbonate of lime per acre as a first application, this to be followed every four or five years thereafter—or every time the corn crop comes around in rotation—by half the above quantities.

Lime cannot be satisfactorily applied with the ordinary fertilizer drill, as it does not sow enough and will not feed slaked lime regularly. Several good lime spreaders are now on the market.

While, as above stated, the need for lime is doubtful over the western half of the state, the case is very different over a large part of eastern Ohio, where the rock floor is made up of shales and sandstones. At the Experiment Station lime is adding six to eight bushels of corn to the acre, two or three bushels each of oats and wheat, and is more than doubling the clover crop.

The Ohio Agricultural Commission has been authorized by law to extend to the trade in agricultural lime the same control now exercised over that in fertilizing materials.

WHAT CROPS TO LIME

In the experiments reported in this bulletin the lime has been applied to corn, in a 5-year rotation of corn, oats, wheat and clover, the lime being spread on the surface and harrowed in after plowing the land, and the outcome seems to have abundantly justified this practice. Many farmers, however, prefer to apply the lime when preparing for wheat, because the rush of work is not so great at that season and because the roads are usually in better condition then for hauling the lime.

Reference to the preceding tables will show that if we should take the average gain for lime on the land receiving the complete fertilizer carrying 30 pounds of nitrogen—Plots 17, 21, 23 and 24—and were to value corn with its stover at half a dollar per bushel, oats with its straw at one-third of a dollar, wheat with its straw at 90 cents and hay at $8.00 per ton, we would have the following as the value of the increase in the different crops due to the liming:

	Increase	Value
Corn, bus	10.25	$5.12
Oats, bus	1.70	0.57
Wheat, bus	3.53	3.18
Clover hay, tons	0.66	5.28
Timothy hay, tons	0.735	5.88
Total		$20.03

On these valuations the greatest gain from the liming has been found in the timothy crop, while the clover and corn have shown a nearly equal gain.

Attention has been called to facts which seem to indicate that a large part of the increase following lime should be ascribed to its action in favoring nitrification, but if it is to serve this purpose effectively it must be incorporated with that stratum of soil in which the nitrifying organisms perform this service and which is the same stratum in which the roots of corn and other crops find their sustenance; for the nitrifying organisms are living plants, whose existence depends upon the same conditions of moisture and air circulation required by corn roots. If the corn roots are exposed to free circulation of air they quickly perish; but they also perish if deprived of air for any length of time, as by being covered with water. Moisture is essential to their life, but an excess of water is fatal, because it excludes the air.

In one respect the corn roots have the advantage of the nitrifying bacteria; they may travel considerable distances in search of food, being connected a' all times with s base of supplies in the stalk, from which they are pushed forward, but the bacteria have no

such support, each minute organism being independent of all others and dependent solely upon the means of subsistence with which it finds itself in contact.

If, therefore, lime is to perform its full function in the soil it must be distributed throughout that layer of the soil which contains the necessary conditions of moisture and air circulation for the growth of crop roots, and must be so distributed that a particle of lime may be found in contact with every particle of soil.

When the lime is reduced to a fine powder, as by burning and slaking, or by grinding, and is then stirred into the surface of a plowed field the first steps have taken for its most effective service. The further stirrings which take place in the cultivation of the corn crop and in the plowings for the oats and wheat crops produce a still more intimate admixture of the particles of lime and soil, so that by the time the clover seeds are sown the conditions are as favorable as we can make them.

To delay the liming until the land is being prepared for wheat means a much less perfect mixture of lime and soil than results from liming the corn crop, and consequently a less perfect utilization of the lime by the clover, although it is much better to lime the wheat crop than not to lime at all.

It is sometimes asked whether the final outcome will not be the same, after a system of liming is established, whether the lime is put on the wheat or corn. The reply is that the necessity for repeating a dressing of a ton per acre of lime or limestone every four or five years means that much of the lime is lost, whether by being dissolved and carried into the drainage waters, or by being fixed in unavailable form; for the consumption of lime as plant food is comparatively insignificant, as shown by the table below, giving the calculated amounts of lime carried off the land by the average crops grown on the limed ends of Plots 17, 21, 23 and 24 in the experiments above described:

Crop	Average yield per acre		Pounds of lime (CaO)	
	Grain bus.	Stover, straw or hay lbs.	In grain	In stover, straw or hay
Corn	57.18	2.658	0.96	14.24
Oats	49.73	2.574	1.75	12.87
Wheat	27.82	2.876	0.83	7.76
Clover	.....	3.815	....	76.30
Timothy	.....	4.514	....	14.40

A total of 129 pounds of lime, equivalent to less than 250 pounds of limestone. Experiments have shown, however, that we never recover in the increase of crop more than 60 to 80 percent of the phosphorus or potassium given in fertilizers or manure, and the

same principle no doubt applies to the recovery of lime, so that it is probable that an annual application of 80 to 100 pounds of limestone would be required to replace that taken off by such crops as those grown in these experiments. But experience has shown that the chief purpose of liming the land is not to supply lime as plant food, but to promote nitrification and to correct soil acidity, and for these purposes the lime must be used in much larger quantity than would be required were its function limited to the direct feeding of the plant.

In performing these functions the lime enters into combination with the soil acids, forming neutral salts, some of which are soluble and are carried into the drainage waters. In the case of the cereal crops the chief function of lime is apparently to favor the action of the nitrifying bacteria, through whose agency the nitrogen held in the remains of previous vegetation is made available, probably in the form of nitrate of lime. Thus we see that Plot 8, which receives phosphorus and potassium, but no nitrogen, produces less grain on the unlimed land than any of the plots which receive the same quantity of phosphorus and potassium with nitrogen in addition. When lime is added, however, Plot 8 produces more corn than any of the plots which receive nitrogen but no lime, although on the limed land the addition of nitrogen to phosphorus and potassium causes a further increase in yield. In the oats crop the effect of lime is too small to justify definite conclusions. In the wheat crop the increase from lime is smaller than that from nitrate of soda, but greater than that from other carriers of nitrogen, thus indicating that much of the effect of lime is due to the making available of organic and ammonia nitrogen.

In the clover crop nitrogen produces no increase on the unlimed land when given in other carriers than nitrate of soda, and the increase from this salt is apparently due to the sodium, rather than to the nitrogen contained.

These facts seem to justify the conclusion that the lime applied to the corn crop in liberal quantity has encouraged the production of nitrates for several succeeding crops, and has furnished a sufficient quantity of alkaline base to neutralize any excess of nitric acid produced, beyond the capacity of the crops to utilize it, and thus has prepared a neutral soil in which the clover has found the conditions essential to its full development.

The increase in the timothy crop may be accounted for in part in the advantage gained by its association with clover, but the darker color of the timothy growing on limed land is evidence that it is having access to a larger supply of nitrogen than is found in the unlimed land, thus again suggesting that much of the effect of lime is due to its forwarding of nitrification.